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THE
DYNAMIC UNIVERSE

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BY

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A

TO MY BROTHER

HAROLD STEELE MACKAYE

WHOSE ENCOURAGEMENT FIRST LED ME

TO PURSUE THE SPECULATIONS

HERE RECORDED

PREFACE

In the preparation of the following work several members of the faculty of Dartmouth College have been at no little trouble to help me, and I wish here to acknowledge my grateful indebtedness to Professors Charles A. Proctor, Charles E. Wilder and John M. Poor for assistance along physical and mathematical lines, and to Professors Raymond W. Jones, and Gordon W. Allport, now of Harvard University, for translations. In particular I wish to record the co-operation of Doctor George D. Snell, now of Brown University, whose aid in bringing certain important features of the radiation theory to a focus has been invaluable. Indeed, his criticisms, both constructive and destructive, of the entire work have greatly improved it. I also wish to express indebtedness to my friend Leonard B. Buchanan, of Woburn, Massachusetts, whose interest and helpful insight have been unfailing, and to my former teacher, the late Theodore W. Richards, of Harvard University, from whose sympathetic attitude and encouraging words in the earlier and less promising stage of speculation I derived much confidence. That the radiation theory should appeal to the judgment of an authority so well qualified to judge as Professor Richards afforded assurance that I was likely to be somewhere near the right track, and later developments have not diminished that presumption.

Hanover, New Hampshire,
July, 1930.

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INTRODUCTION

THE following chapters present a cosmological theory dealing with the structure, and cause of change of motion, of material bodies. It is little more than a provisional outline, but the presumption of its soundness appears sufficient to justify presentation in its present incomplete and non-mathematical form, particularly as it offers promise of in some degree clarifying the confused condition of theoretical physics which now prevails. That condition is largely due to speculations associated with the relativity equations, and as the theory herein presented leads to a reinterpretation of those equations, it may appropriately be approached by a consideration of the corresponding speculations.

The philosophy of relativity is a union of physics and metaphysics, combining truth and untruth in a manner qualified to obscure the cosmic clue contained in the equations of relativity. To reveal that clue is an essential task in the exposition of the theme of this work. An initial step in that exposition then may well be one which seeks to disunite the union of obscurity at present prevailing, and in the chapter following will be undertaken an effort to that end.

To the physicist the evidence referred to, and terms used, in this work will be familiar, but to others some explanation may be of service.

There are four critical experiments associated with the theory of relativity, the nature and results of which may be briefly described, as follows:

(1) The Fizeau experiment, repeated by Michelson,

Morley and Zeeman, consisted of a comparison between the velocity of light in stationary and moving water. The result was positive, indicating that the water dragged or drifted the light with it, but changed its velocity by only a fraction of the velocity of the water. This fraction increases with the index of refraction of the dragging medium, as assumed by Fresnel, and proved by Zeeman in his experiments using denser materials than water as media.

(2) The Airy experiment, which consisted in comparing the aberrational angle of a star (or stars) using first a telescope filled with air, and then one filled with water. The result was negative, the angle of aberration being the same whether the tube of the telescope was filled with air or water. This angle is that which measures the relation between the velocity of light (from the star) and the velocity of the earth in its orbit. It is about 20.5″, corresponding to an average orbital velocity of the earth of something less than 19 miles a second. Fresnel explained this negative result on the same grounds on which the positive result of the Fizeau experiment was explained, namely, by the drag of the ether carrying the light by the water in the telescope, which, of course, moves with the earth. This is one of the many compensation effects associated with radiational phenomena.

(3) The Michelson-Morley experiment, which consisted in comparing the velocity of light in two directions at right angles to each other relative to the fixed stars, the two velocities being those perceptible by an observer on the earth and moving with it. It is generally agreed that the result was negative, though Miller, a highly competent authority, disputes this. Into the technical questions involved in this difference of judgment,

we cannot enter here. It must suffice to say that the result is different from what is to be expected on the assumption that the earth is moving through a stationary ether and no compensation effects intervene, since on such an assumption, the result should be positive and reveal the motion of the earth in its orbit, as well as its absolute motion. The possible causes of compensation proposed as explanations of this negative result will be discussed in later pages.

(4) The Kaufmann-Bucherer experiment, which consisted in comparing the deviations at varying velocities of cathode rays (moving electrons) from a straight path, caused by a magnetic field. These deviations were found to decrease with increasing velocity in a greater degree than required on the assumption that the inertial mass of the electrons (which resists the deviation) remains constant. The inference from this result has been, therefore, that the inertial mass increases with velocity according to a law referred to later in this exposition. Thus the result may be considered positive, so far as revealing an increase of inertial mass with motion is concerned.

For a more thorough description and discussion of the first three experiments, the reader should consult some standard work on optics, such as *Physical Optics* by R. W. Wood, or *The Theory of Light* by Thomas Preston. I do not happen to know of a satisfactory account of the details of the fourth experiment in English, but they may be found in *Phys. Zeit.*, vol. 4, p. 54, and *Ann. Physik,* vol. 28, p. 513, and vol. 19, p. 487. A sufficient understanding of its results is, in any event, obtainable without them.

It will be noted that in three of the four historical experiments listed above, a variation in the motion of mat-

ter relative to radiation is involved, whereas in one (the last named) it appears not to be involved. Yet the relativity equations apply to the result of all four experiments. It will be well to keep this in mind in following the interpretation of the relativity theory hereinafter expounded.

There are three other matters to which it will be useful to call the attention of the non-professional reader in this Introduction:

First, the meaning of a Doppler-displacement. When a source of waves—whether water, sound or light waves—moves relative to the medium in which the emitted waves travel as they move outward from the source, it does not cause any change in the velocity of the waves relative to the medium. Thus it does not impart its own velocity to the waves as it would to a mechanical particle shot out from it. Instead of doing this, it simply crowds the waves closer together in front and thins them out behind, because it changes its velocity relative to the waves which it is itself emitting. Thus it changes the wave-length and frequency of the waves, together with their energy and momentum, relative to the medium, instead of changing their velocity relative thereto. This is what is meant by a Doppler-displacement. Obviously it is different in different directions, the changes of frequency, wave-length, etc., being a maximum along the axis of motion of the source and diminishing to zero in a plane at right angles to that axis. The name Doppler effect is generally given to the change in wave-length caused in this manner, but this is not the only change involved in the displacement. The energy and momentum are changed also because they are inversely proportional to the square of the wave-length.

Second, the Lorentz transformation. Previous to Einstein the relation between measurements of length and time in two Cartesian co-ordinate systems in motion relative to each other, had been expressed by what may be called the Newtonian (Galilei) transformation, in which the motion of a given point in space, as visually observed from the two systems respectively, was compared on the virtual assumption that light moves with an infinite velocity. In short, correction was made for the finite velocity of light in order that said velocity might not enter into the location of points in space and time. The Lorentz transformation constitutes the new method of comparing lengths and times characteristic of Einstein's special theory. It differs from the earlier system in that it makes no correction for the velocity of light, but leaves the measurements exactly as they appear to observers using light as a means of observation. Thus, as Einstein says:

"The Galilei transformation can be obtained from the Lorentz transformation by substituting an infinitely large value for the velocity of light c in the latter transformation."[1]

The method of comparison will be found explained in Section 11 of the book referred to, and the resulting redefinitions of time and length (from the origin of corordinates) appear on page 40 of the present volume. The characteristic "relativity" effects are those which appear when the Lorentz transformation is substituted for the Galilei as a mode of measuring length and time from systems in relative motion. Inspection of the equations makes it plain that when the relative motion of the two systems is expressible by an approach or recession parallel to the x-axis, no relativity corrections are called for on obser-

[1]Einstein, A., *Relativity*, 2d edition, p. 33.

vations made along the y- or z-axes. That is, the relativity effects become zero. They appear, however, in all other cases; which means that when the relative motion with which these effects are associated involves no component of approach or recession, the effects disappear. The reason for this will appear in Chapter V, Section 2.

Third, the evidence that material particles—or, at any rate, those constituents thereof consisting of electrons—are composed of radiation, or mechanical waves, so called. This can be found in any authoritative work on the modern wave-structure theory of matter, such as that by H. T. Flint, entitled *Wave Mechanics,* and particularly in the experiments of Davisson, Germer, and Thomson referred to therein.

With the help of the experimental results noted in this Introduction, together with various other pertinent data, let us begin our attempt to look through the ponderous millstone of relativity, and see if by putting two and two together we cannot discover something of cosmic interest on the other side of it. A wide variety of physical discoveries have provided significant fragments of evidence for the presence of this something in the universe, but the theory of relativity appears to have presented physics with the missing link required to render that evidence all but conclusive.

CHAPTER I

SEPARATING THE PHYSICS FROM THE META-PHYSICS OF RELATIVITY

DESPITE the standing of the theory of relativity in our day, few physicists pretend to understand it. Their position generally is one of suspended judgment. They acknowledge the competence of its sponsors and its power to predict, but its language puzzles and its paradoxes perplex them. A situation of great confusion prevails. There are reasons for believing that this state of affairs may be traced to two causes; first, a verbal confusion due to the violation of certain rules of intelligibility; and, second, a mistaken identity of magnitudes. Let us turn for a moment to an historic parallel.

Some eighty-odd years ago J. D. Mayer discovered what he called the law of the conservation of "force." But at first men mistook the identity of the magnitude subject to conservation. They mistook force for energy. The situation which resulted threw the physics of energetics into a controversial chaos which lasted for years. The present situation in the physics of relativity is similar and due apparently to similar causes. The first step in clearing this situation is to distinguish what is verbal from what is real in the theory of relativity. A similar step led to the clearing of Mayer's discovery, and only school boys now mistake force for energy. With this end in view let us at the outset inquire whether time and space have by Einstein been *discovered* to be relative, or simply *defined* to be so.

In his book, *Relativity,* we are clearly informed about this. Thus he says:

> "There is only *one* demand to be made of the definition of simultaneity, namely, that in every real case it must supply us with an empirical decision as to whether or not the conception that has to be defined is fulfilled. That my definition satisfies this demand is indisputable. That light requires the same time to traverse the path $A \rightarrow M$ as for the path $B \rightarrow M$ [M is a point midway between the points A and B] is in reality neither a *supposition* nor a *hypothesis* about the physical nature of light, but a *stipulation* which I can make of my own freewill in order to arrive at a definition of simultaneity."[1]

Note that the constancy of the velocity of light, which plays so prominent a part in relativity, is not an hypothesis, neither is it a discovery. It is a stipulation involved in the *meaning* of the term "simultaneity" (sametimeness), as four-sidedness is involved in the meaning of the term "square," or the possession of a spinal column in the meaning of "vertebrate."

In short, it follows from Einstein's *definition* of simultaneity, and hence, as he says, is "indisputable" because it is true by definition. Thus if a is the time light takes to

Fig. 1

A ***M*** ***B***

go from A to M (Fig. 1), and b is the time it takes to go from B to M, then the name "same" is applicable to the relation between the two time intervals, no matter what

[1]Einstein, A., *Relativity,* p. 23. All references are to the second edition.

ordinary clocks or physical measurements may say about it.

Seeking further, we find that on page 23 he tells us that by the definition of "simultaneity," already established by stipulation, "we . . . are led . . . to a definition of 'time' in physics." And in Section 11, he shows that through these stipulations he is led to his definition of "length"* in physics, and thus to the well-known "Lorentz transformation" which expresses the relativity of time and space (according to the special theory). Lorentz had already arrived at these equations, reasoning from a non-relativity theory. Throughout this part of his work, in fact, we find Einstein doing what every competent scientist does when he finds that custom does not provide him with definitions sufficiently sharp or otherwise suited to his purpose. He proceeds to stipulate them of his own freewill and assign them to such symbols (terms) as he chooses. He does this, because if he does not, he has no means of referring to them—and he has occasion to refer to them. It is an eminently reasonable proceeding, and scientists are continually doing it. If they did not, science could not grow. And Einstein by his stipulation of new definitions has caused science to grow. It is not in doing this that he has violated the rules of intelligibility. Quite the contrary. His violation of those rules is his failure to take the next step and give his new meanings new names.

Now we find the assumption constantly made that the "theory" or "principle" of relativity is expressible in the statement that "time and space are relative," and this assumption is either correct or it is not. If it is, then the "theory" cannot record a discovery, since it consists

*A relativity of length involves a relativity of space, since the dimensions of volume (in units of which space is measured) are L^3, where L means length. Thus space becomes relative because length is defined to be.

merely of a set of truisms or tautologies.* If, however, the assumption is not correct, then, if Einstein has made a discovery it cannot be the discovery that "time and space are relative." Now Einstein has made a discovery, and the above reasoning simply shows one discovery which he has *not* made. What then is his discovery? Is it embodied in the theory of relativity? If so, what *is* that theory? The writings of the relativists show that it is not less than three different things, left undistinguished by them. These are:

(1) The definitions of time and length and their derivative magnitudes derived from the Einsteinian definition of simultaneity on page 18, or corollaries thereof.

(2) Certain assumptions, specified in Chapter VI, which these definitions have caused the relativists to adopt in their attempt to reduce physics to geometry.

(3) The assumption that if the Einsteinian definitions of time and length are substituted for the Newtonian definitions in statements (equations) expressing laws of interaction between bodies moving relatively to one another, results agreeing more closely with observation will be obtained than by failing to substitute them.

Here are three different assumptions (or sets of assumptions) to which the term "theory of relativity" is applied by the relativists. Which of them, if any, is confirmed by the facts? The first, like all assumptions based on definition, is a verbal one. The second and third are

*It is evidently this fact which Russell is referring to when, in discussing the effect on physics of the relativity theory, he says:

"Broadly speaking, traditional physics has collapsed into two portions, truisms and geography." (Russell, Bertrand, *The A B C of Relativity*, p. 222.)

The truisms are the disguised definitions referred to in the text. The geography is the allegorical geometry referred to in chap. VII, which gives these truisms the misleading appearance of physical explanations.

material assumptions. The first "theory" then is a certainty, exactly comparable to the "theory" that a triangle has three sides or that a circle is circular. The second theory will be shown in Chapters V to VII inclusive to be incompatible with the facts of physics, and hence refuted by them. The third theory is very closely confirmed by many facts of physics, approximately confirmed by others, and apparently contradicted by none. *It is this third theory which embodies Einstein's discovery.* It is a purely empirical discovery, not anticipated by the classical physicists, and still remains a mystery both to them and the relativists themselves.

Examination of Einstein's work shows that he has constructed by definition a series of ideal magnitudes, to which he has assigned the names "time," "length," "space," "velocity," "energy," etc. In so doing he is following the rules which guide the pure mathematician, and Eddington tells us that: "The pure mathematician deals with ideal quantities defined as having the properties which he deliberately assigns to them."[2] That is, Einstein does not *discover* properties (*e. g.*, relativity) of time, space, etc., by *observation.* He *assigns* them by *stipulation.* In short, he begs the question of whether time, space, length, energy, etc., are relative or not by defining them to be so, thus removing the issue from all debate. No doubt it may appear strange that a procedure for settling questions by begging them can be of any service in physics or anywhere else, but this strangeness will disappear if we recall that words are, first of all, attention directors. And he, who, by suggesting new, or more definite, meanings of words, directs the attention of scientists to magnitudes having physical significance to which their attention has

[2]Eddington, A. S., *The Mathematical Theory of Relativity,* p. 1.

not been previously directed, is doing science a service. It is this kind of service that Einstein has done by his new definitions of time, space, etc., and that Mayer did by his new definition of force, for Mayer merely *stated* the law of conservation. The labors of many physicists were required to establish it. Suppose then we examine the history of Mayer's discovery, the better to understand the present situation of Einstein's.

In Mayer's time the subject which is now called energetics, or perhaps more commonly thermodynamics, was undeveloped. Men saw the relationships of such things as motion, heat, force, acceleration, momentum and various other physical phenomena, through a sort of fog. That there was some connection between these things, or some of them, appeared probable, but its nature was obscure. The fog began to lift with the work of Count Rumford; and Grove, Joule, Helmholtz and others contributed to the clearing process. Mayer, however, is most commonly given the credit for the discovery which made the main relationships plain. His discovery, now called the law of the conservation of energy, was at first called a law of conservation or correlation of force. The name "energy" was first used by Young in 1807, but when Mayer attacked his problem, the meaning for which the name now stands had not come clearly to the attention of physicists. The physical significance of the magnitude at present so-called was unknown. Such things as heat, motion, force, power, kinetic energy, mechanical energy, pressure, etc., were lumped together under the name "force." Mayer became convinced that there was some sort of equivalence or correlation to be found among these things. He saw signs, as Rumford did, that "force" is conserved in some way—that when a given "amount" disappears in one form an

"equivalent" amount appears in another. It was all very vague at first. The question which plagued him most was, What *is* force? What are physicists trying to mean by that word? And what do they mean by "amount of force"? Without going into the many understandings which arose from the multiplicity of meanings of these terms which then prevailed, we may simplify matters by selecting two of the many meanings of the word force then prevalent, for comparison. Let us call them force *A* and force *B*, and define them as follows:

Force *A* means the agent which causes, and is proportional to, the acceleration which it produces in a given material body.

Force *B* means heat, or anything which can be converted (by processes such as are familiar to physicists and chemists) into heat.

Without pretending that these definitions are flawless, let us ask which of these kinds of force it is which is constant, or conserved in an isolated system, if either? Which is it which on disappearance in one form reappears in another in equivalent amount? To get these two different magnitudes separated out and defined was a laborious and long task, and it was another task of the same kind to discover the meaning of the word "amount" as applied to them. For "amounts" are things which imply methods of measurement and units by which to measure, and they were hard to find in the maze of metaphysics in which Mayer wandered. To make a long story short, it was finally discovered that force *B* is the kind of force that possesses the property of "conservation." Force *A* has not this property. Force *B* was then given a name of its own—it was called energy—and the misunderstandings disappeared. But they did not disappear till this was done.

As long as the two magnitudes were both called "force" all kinds of paradoxes arose. Force appeared to be something which it is *not*—and naturally enough—for force *A* is *not* force *B*.

In view of present controversies about "space" and "time," Mayer's comments on the word "force," as then used, are worth noting:

> "However happy we may, in many respects, think the choice of this word [force], there is still the objection that a new meaning has been fixed upon an already existing technical expression, without the old one having been called in from circulation at the same time. This formal error has become a Pandora's box, whence has sprung a Babylonian confusion of tongues."[3]

To-day physics is plagued with another Babylonian confusion centering in the theory of relativity. It has apparently been discovered that time and space have the property of relativity, something not suspected by the older physicists. But what *is* time? And what *is* space? What are physicists trying to mean by these words? And these questions are fully as hard to answer as similar ones about "force" in Mayer's time. Can it be that a similar confusion of meanings is at the bottom of the trouble? Has "a new meaning been fixed upon an already existing technical expression without the old one having been called in from circulation at the same time"? Or have several new meanings been thus fixed even? In view of the experience of physicists of Mayer's generation, the hypothesis seems plausible. At least it might be worth looking into.

[3]Mayer, J. D., "The Mechanical Equivalent of Heat," in *The Correlation and Conservation of Forces,* a series of expositions collected by Edward L. Youmans, M.D., 1865, p. 333.

To cover the whole subject, however, and attempt to straighten out all the meanings, would be too long a story. Suppose then we restrict attention to the germ of the trouble. Einstein starts his series of (new) definitions by defining "simultaneity." Let us therefore focus on that word and its present meanings. If we should find that it stands for two different meanings, one of which has the property of relativity and the other not, and that *both* are in the minds and language of modern physicists, we should begin to see a light.

A study of the subject reveals the fact that the trouble begins when we try to say what we mean by the simultaneity of two events when the events occur at two different points in space. In this case it is clear that the observation by one and the same observer, of at least one of these events, can only be made by means of a signal of some kind proceeding from event to observer. This follows from the fact that an observer cannot be in two different places at the same time. There is a genuine puzzle here, and the best way to approach its solution is first to ask ourselves what we mean by simultaneity when the two events whose simultaneity is to be tested occur at the *same* point in space, or sufficiently near for the purpose. Suppose an observer to watch two flashes caused by an electric spark jumping two gaps placed close together, so that both are within the field of his vision as he gazes steadily at them, and suppose both to be near him and equally near. Suppose also they are not in motion relative to him. Then, assuming him to be a sufficiently acute observer of time intervals, if he observes the two flashes, but fails to observe any sensation of succession between them, the two flashes occur (by definition) at the same time. Otherwise they do not. In other words, this is

what we *mean* when we say the two flashes are simultaneous. We stipulate this meaning of our own freewill. Any two flashes (which may be deemed samples of events in general) will not conform to the definition of simultaneous flashes if they are unable to meet this test. It will be noticed that this method of definition uses psychical simultaneity—a feeling—as a test of physical simultaneity, which is the kind of simultaneity of interest to physicists. We mention this here, because a like method is used by Einstein.

Let us next distinguish two different meanings of the term "simultaneity" at *different* points in space. For brevity we will call these, simultaneity N and simultaneity E. Simultaneity N may be defined as follows:

Let A and B (Fig. 2) be any two points in space, and let M be a point in space also (which may coincide with either A or B or may not). Let x be the event occurring at A and y the event occurring at B. Let an observer be stationed at M, and assume an agent moving with infinite

Fig. 2

velocity and capable of affecting the retina (or any other observing organ) of the observer to transmit signals of the occurrence of x and y to M. Assume also that the departure of the signal from A and B respectively is simultaneous with the occurrence of x and y respectively, as tested by observers at A and at B. If these two signals are

observed simultaneously, that is, if the two signals produce the impression of psychical simultaneity in the observer at M, x and y are simultaneous (by definition). Otherwise they are not. And this test of simultaneity will hold whether M is moving relatively to A and B or not.*

If the reader cares to take the trouble to examine this definition, he will find that it coincides with his own, though he has probably never tried to express to himself the definition of the term here defined. I am not aware indeed that the meaning of Newtonian simultaneity (N) has been previously expressed with an explicitness sufficient to raise an issue with Einsteinian simultaneity (E).

Let us now turn to the definition of simultaneity E, and as this is not as easy to define as simultaneity N, we shall let an authority who has given close attention to the subject define it for us. We shall thus be guarded against possible error. Turning then to Einstein's *Relativity*, we find that he first asks the reader to imagine a straight railway embankment with a train running on rails laid thereupon, both embankment and train being provided

*If objection be made that the definition of simultaneity N above stipulated is not allowable because it involves the assumption of a physical impossibility, no agent moving with infinite velocity being available to men by means of which to observe events; the answer is that physical impossibilities may be postulated for purposes of definition with entire propriety, and often are. An "absolutely rigid body" is one whose rigidity is infinite. We have no reason to believe that it is a physical possibility. Yet physicists understand the meaning of the term and use it as a means of working out formulæ applicable in mechanics. "Carnot's engine," "frictionless surface" are other examples of terms defined by postulating the physically impossible. If a process of definition succeeds in conveying the meaning desired no more is required of it, and any expedient is justified which achieves this end. Moreover, the objection applies equally to Einstein's definition of simultaneity E. The operations there described are entirely imaginary. They have never been used to distinguish simultaneity E from simultaneity N, and in any case open to actual experiment by human beings, it would be physically impossible to use them. Nevertheless, the defining process which Einstein uses conveys his meaning, and no more need be asked of it.

with observers, like the one described on page 15, having superhuman powers of distinguishing the feeling of psychical simultaneity from that of psychical succession. He then proceeds:

"Lightning has struck the rails on our railway embankment at two places *A* and *B* far distant from each other. I make the additional assertion that these two lightning flashes occurred simultaneously. If I ask you whether there is sense in this statement, you will answer my question with a decided 'Yes.' But if I now approach you with the request to explain to me the sense of the statement more precisely, you find after some consideration that the answer to this question is not so easy as it appears at first sight. . . .

"After thinking the matter over for some time you then offer the following suggestion with which to test simultaneity. By measuring along the rails, the connecting line *AB* should be measured up and an observer placed at the mid-point *M* of the distance *AB*. [Fig. 3.] This observer should be supplied with an arrangement (*e. g.*, two mirrors inclined at 90°) which allows him visually to observe both places *A* and *B* at the same time. If the observer perceives the two flashes of lightning at the same time, then they are simultaneous."

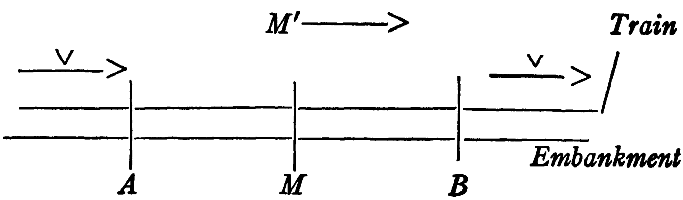
Einstein says he is "very pleased with this suggestion," and in the next section proceeds as follows:

"We suppose a very long train travelling along the rails with the constant velocity v, and in the direction indicated in Fig. [3]. People travelling in this train will with advantage use the train as a rigid reference-body (co-ordinate system); they regard all events in reference to the train. Then every event which takes place along the line also takes place at a particular point of the train. Also the definition of simultaneity can be given relative to the train in exactly the same way as with respect to the embank-

ment. As a natural consequence, however, the following question arises:

"Are two events (*e. g.*, the two strokes of lightning *A* and *B*) which are simultaneous *with reference to the*

Fig. 3



After Einstein, *Relativity*, p. 25.

railway embankment also simultaneous *relatively to the train?* We shall show directly that the answer must be in the negative.

"When we say that the lightning strokes *A* and *B* are simultaneous with respect to the embankment, we mean: the rays of light emitted at the places *A* and *B*, where the lightning occurs, meet each other at the mid-point *M* of the length $A \rightarrow B$ of the embankment. But the events *A* and *B* also correspond to positions *A* and *B* on the train. Let *M'* be the mid-point of the distance $A \rightarrow B$ on the travelling train. Just when the flashes* of lightning occur, this point *M'* naturally coincides with the point *M*, but it moves towards the right in the diagram with the velocity *v* of the train. If an observer sitting in a position M' in the train did not possess this velocity, then he would remain permanently at *M*, and the light rays emitted by the flashes of lightning *A* and *B* would reach him simultaneously, *i. e.*, they would meet just where he is situated. Now in reality (considered with reference to the railway embankment) he is hastening towards the beam of light coming from *B*,

whilst he is riding on ahead of the beam of light coming from *A*. Hence the observer will see the beam of light emitted from *B* earlier than he will see that emitted from *A*. Observers who take the railway train as their reference-body must therefore come to the conclusion that the lightning flash *B* took place earlier than the lightning flash *A*. We thus arrive at the important result:

"Events which are simultaneous with reference to the embankment are not simultaneous with respect to the train, and *vice versa* (relativity of simultaneity). Every reference-body (co-ordinate system) has its own particular time."[4]

*"As judged from the embankment."

Thus the definition of simultaneity *E* (Einstein's definition) is *different* from that of simultaneity *N*, which is Newton's definition, this latter being the definition of the classical physicists and of the "man in the street." Hence the suspicion which arose on page 14 is justified. Modern physics has two meanings for the word *simultaneity* and only one name, just as the physics of Mayer's time had two meanings for the word *force* and only one name. And this is why the Babylonian confusion which beset physics in his time has reappeared in our own.

The fact is that, previous to Einstein, no physicist had troubled himself to define the term "simultaneity" very sharply, though the definition of simultaneity *N* was tacitly assumed. There is a reason for this. Physicists prior to Einstein had not troubled themselves to give the word "simultaneity" a sharp meaning for the same reason that physicists prior to Mayer had not troubled themselves to give the word "force" a sharp meaning. Words are tools of thinking, and as carpenters sharpen their tools only when they are not sharp enough for purposes of car-

[4]Einstein, A., *Relativity*, Sections 8 and 9.

pentry, so scientists sharpen theirs only when they are not sharp enough for purposes of science. Not until some new distinction of significance begins to be perceived do they trouble to look more closely into their meaning—and then the meaning generally splits into two (or more). A new magnitude of physical significance was discovered by Mayer, and another one was discovered by Einstein. Mayer's discovery caused the meaning of the term *force* to split into two (and more) meanings. Einstein's discovery caused the meaning of the term *simultaneity* to split into two meanings. And future discoveries may cause it to split into twenty. And the relativists have assumed that only one of these meanings is the *real* one. The fact is the issue of "reality" between definitions is an idle one. It is true that Einstein calls his definition "the most natural" one (*Relativity,* p. 27)—whatever that may mean—but it is man, not nature, that assigns meanings to terms. The combinations of letters which constitute the words of ordinary language, or the single ones which constitute the language of the mathematician, have no "natural" meanings. If man assigns no meanings to them they have none. Nature determines what meanings it is convenient for man to direct his attention to. It is man who determines what symbols shall be selected to act as attention directors.

It is well known that the units of most measurable physical magnitudes can be expressed in terms of three fundamental units, those of length (L), time (T) and mass (M). These expressions are called the *dimensions* of the magnitude. Thus the dimensions of area are L^2, of volume L^3, of velocity $\frac{L}{T}$, of force $\frac{ML}{T^2}$, etc., etc. Hence a double meaning of simultaneity, involving as Einstein

shows it does, a double meaning of time and length, involves double meanings of most measurable physical magnitudes.

Eddington notes this fact, without noting its significance as a cause of verbal confusion, when he says:

> "You may have seen one of those tables of 'dimensions' of physical quantities showing how they are all related to the reckoning of length, time and mass. If you alter the reckoning of length you alter the reckoning of other physical quantities."[5]

And if you alter the reckoning (meaning) of time also, as Einstein does, you alter the meaning of all physical magnitudes derived from these two fundamental ones. *This means that the failure to give the two meanings of simultaneity above distinguished two different names involves ambiguity in the expression of most physical magnitudes. The confusion caused by this failure does not need to be imagined. It can be observed wherever the theory of relativity is discussed. Nevertheless, it may be readily abolished. We need only follow the precedent set* by Mayer and his followers. Suppose we call simultaneity *N,* Newtonian simultaneity, and simultaneity *E,* Einsteinian simultaneity. Then the magnitudes derived from the former will have the name Newtonian, and those derived from the latter Einsteinian.

In adopting this simple verbal expedient, we are merely imitating the practice of the mathematician, who assigns separate signs to separate meanings by the use of different letters, sub-numbers, or the like, thereby avoiding confusion. Hence the relativist, as a mathematician, does not find himself subject to the paradoxes from which he

[5]Eddington, A. S., *The Nature of the Physical World,* pp. 21, 22.

suffers as a physicist, because, as a mathematician, he adheres to the rules of intelligibility.

Thus in place of the statement, so commonly made by physicists, that "Time and space are relative"—which is ambiguous—we shall have two statements, namely, that "Einsteinian time and space are relative," and "Newtonian time and space are not relative," and these two statements will be both unambiguous and true. The corresponding changes required to abolish the "conservation" confusion were the same, but it so happened that the new meaning was given an entirely new name (energy) and the old one retained unchanged. This accomplishes the same result as the method adopted above, of retaining the old name and qualifying it by two different adjectives. *The original statement encountered by Mayer was "Force is conserved"—which was ambiguous. By means of the new definitions this was split into two statements, namely, "Energy is conserved" and "Force is not conserved," and these two statements were both unambiguous and true.*

When there is no relative motion of event and observer, the two kinds of simultaneity, time, space, etc., coincide, because the two definitions will call for the same numerical value. In this case, then, there will be no ambiguity, and we find, as we should expect to find, that in this case there is no confusion about "relativity." The relativists and the non-relativists agree because their definitions call for the same numerical expression—and this is another indication that the controversy between them is verbal.

Einstein's new discovery then is not that time and space are relative. That is merely new definition. His discovery is that the new definitions have physical significance, as proved by the fact that their use in his formulæ gives him the power to predict what will actually happen in the

world observable by human beings more accurately than formulæ which use only the old definitions. And this is a great discovery, comparable with Mayer's in its earlier stage, because prediction is one of the great objects of science. But the fact of this physical significance is not explained, as commonly assumed, by saying it is due to the discovery that time and space, contrary to what had previously been supposed, really have the property of "relativity." Of course, the kind of time and space referred to in such a statement have this property because it is a part of the definition of the words. Suppose I should formulate a new definition of the word "triangle" as a four-sided figure of some kind—perhaps a trapezium, one side of which is so short that the figure is almost a triangle—and a surveyor by using this definition in his formulæ—thus applying my novel "transformation"—should discover that he could get results which checked up with experience more accurately than by using the old definition of a triangle. This would be a truly surprising empirical discovery—and one calling for explanation. But it would not be explained by saying that it was all due to the fact that "triangles," contrary to what had previously been supposed, really have the property of "four-sidedness." Such an explanation is merely a statement that a triangle defined as having four sides, has the property of four-sidedness.

Thus the fact that Einstein's new definitions have physical significance is not explained by their "relativity." The physical significance of this relativity is the fact *to be* explained. And thus far no explanation has been suggested. It is as mysterious as why energy has the property of conservation—something which cannot be explained by saying "because it is conserved." But Ein-

stein's discovery, though unexplained, is not necessarily unexplainable. It so happens that the discovery does not stand by itself. Physics provides us with other discovered facts which can be compared and correlated with it. And perhaps not in vain. At any rate a possible explanation of the facts of relativity, together with some of non-relativity, will be suggested in the following pages. Whether it is a good one or not depends upon its agreement with the sum of the facts to be explained. But having made a beginning in disentangling what is verbal from what is real in the theory of relativity, we shall be the better prepared to test it. The beginning thus made, however, is only a first step. A second one must be taken before it will be possible to uncover the mistaken identity of magnitudes involved in the theory of relativity.

CHAPTER II

DIMENSIONAL AND NON-DIMENSIONAL EXPLANATIONS

In the previous chapter it was noted that Einstein, by changing the meanings of the words time (T) and length (L), obtains equations which are more successful in predicting certain phenomena than those which retain the classical definitions resting on the Newtonian definition of "simultaneity" specified on page 16. Now this is a rather mysterious accomplishment, and, in the words of Bridgman, "the problem for us as physicists is to discover by what process these results were obtained,"[1] a problem which may perhaps receive solution by inquiring whether a similar procedure of redefinition will yield the same mysterious results elsewhere in physics. And on trial we obtain an affirmative answer to the inquiry. It is possible, for instance, to retain the assumption, prevailing previous to Römer, that the velocity of light is infinite, and predict the lag of light signals proportional to distance, actually due to the finite velocity of light (which may be called the d-effect), by redefining "time" according to the following "transformation":

$$(1)\quad T' = T + \frac{d}{186{,}000}$$

where T' is the time in seconds on the observed system, T the time on the observing system, and d the distance in miles between the systems, thus discovering a relativity of time with *distance*. And it is also possible to adopt the

[1]Bridgman, P. W., *The Logic of Modern Physics*, p. 172.

assumption that the earth is a perfect rotationless sphere, and predict all effects on the rate of pendulum swing at different latitudes, actually due to the rotation and oblateness of the earth (which may be called the *l*-effect), by redefining "time" according to the following "transformation":

$$(2) \quad T_l = T_{45}\sqrt{1 - .0025\cos 2l}$$

where T_{45} is the time at 45°, l the latitude, and T_l the time at latitude l, thus discovering a relativity of time with *latitude.*

These are strictly analogous to the Lorentz transformation redefinitions by means of which Einstein "discovered" a relativity of time with *motion.* And if it were necessary many other examples of such "relativity" might be cited.

Thus the process used by Einstein is a special case of a very general one, which may be called the process of discovering "dimensional" explanations, so called because it consists in redefining one or more of the fundamental dimensions, time, length and mass, of which most other physical magnitudes, such as velocity, acceleration, energy, etc., are functions. It may be briefly described as a process for transferring to one or more of these dimensions the variation of physical causes in such a manner that the variation of the cause, if any, is expressed in the formula by a variation (relativity) of the appropriate unit or units, and hence can be attributed to that relativity. Instead of leaving the units constant, as the Newtonians do, and correcting for the varying cause, the cause is assumed constant, and the correction made by varying the unit—both processes giving the same result. Any law of nature,

in fact, empirical or otherwise, may be thus dimensionally expressed, disappearing as a law controlling phenomena, and reappearing as a law controlling the units in which phenomena are measured. All that is required is ability to make the units proper functions of the proper variables. Given the requisite mathematical ingenuity, as many kinds of relative time, length, space, mass, velocity, energy, etc., as we please may be "discovered," and they will all have the mysterious predicting power which the kinds devised by Einstein are found to have.

Indeed, a dimensional explanation is characterized by the fact that it is not an alternative to, but a disguise for, a non-dimensional one—a non-dimensional explanation being one which holds all units constant, and attributes effects to physical causes instead of variation (relativity) of units of measurement. Thus the predicting power of a dimensional explanation is due to the fact that it constitutes a disguise for a non-dimensional one. In the case of the *d*-effect, for instance, the redefinition of time is a disguise for the variation of the lag of the light signal with variation of distance due to the finite velocity of light; and in the case of the *l*-effect, it is a disguise for the variation of gravity with variation of latitude due to the rotation and oblateness of the earth. In thus transferring the explanation to the unit, however, an extraordinary alteration is tacitly made in the concept of cause and effect. Observed effects are no longer attributed to physical agencies, but to mathematical fictions, which can be manipulated at the option of the mathematician. All that is required is a new definition. For it should be noted that these redefinitions of dimensions not only involve a change in the units for measuring physical magnitudes, but introduce a causal connection between the units and

the magnitudes they measure, previously unknown to science. To illustrate baldly the nature of the assumption, suppose a string to be tightly stretched between the ceiling and floor of a room, in a vertical position, the distance between the points of attachment being 10 feet. According to our best information, a string thus stretched would be straight. But suppose that by changing the unit of length to inches, and expressing the length as 120 inches instead of 10 feet, it could be caused to become curved or wrinkled or puckered. Surely a discovery unknown to science about the causal power of units of length would have been made. Suppose, further, that by observing this stretched string while moving relatively to it, an observer could cause the units in which it is measured to change from feet to inches, and thus cause the string to become curved, wrinkled or puckered. Surely another discovery strange to science about motion as a cause of the units in which length is to be measured would have been made. Can it be that discoveries of this character have actually been made? Can we, in truth detect the law of causation acting in this peculiar manner? I know of no reason to believe that we can; but anyone who claims that a dimensional "explanation" *per se* shares the characteristics of other causal explanations, must answer these questions in the affirmative. He must in fact claim that anyone, by the simple process of redefining dimensions, can control the course of nature, just as physical causes can. A person so claiming who thus formulates redefinitions may be called a dimensionalist.

Now it is clear from the facts cited in the first chapter that the relativist is a particular variety of dimensionalist, because he redefines time and length and cites his redefinitions as means of physical explanation. That is, he

claims that the course of nature is different because time and length are relative (by definition) than what it would be if they were not relative (by definition). Thus he mistakes a man-made mode of expression for a law of nature. That is why Eddington claims that "the law of gravitation is a put-up job" (see page 246). In so claiming he deceives himself. The job was put up on the dimensions to begin with, and hence, to the dimensionalist, appears to be put up on the law which his redefinitions are disguising. Dimensionalists might be of many kinds, disguising not only effects due to distance or latitude or motion, but to temperature or pressure, or indeed anything capable of producing physical effects. At present, however, the relativist is the most conspicuous and most useful in advancing physics. It is important to remember, however, that a dimensional "explanation" duplicates and disguises, without opposing, the non-dimensional explanation for which it is an equivalent. It may also accomplish a simplification and hence be more convenient than said equivalent. But whether the two explanations will be in harmony in all cases depends upon the thoroughness of the dimensional adaptation, and this in turn depends upon the ease with which the non-dimensional explanation can be dimensionally disguised. The disguise of the *d*-effect, for instance, is more readily accomplished than that of the *l*-effect. In complicated phenomena it is probable that dimensional explanations cannot, as a rule, be devised to fit all cases, but we cannot affirm it to be impossible. Much depends upon mathematical resourcefulness. The theory of relativity as a dimensional explanation is incomplete, and hence cannot meet all contingencies. It is well known that vast mathematical labors have been expended upon it by Einstein and others in an attempt to complete it, but

despite these efforts it still applies to a restricted class of physical phenomena. The reason for this will become plain when we identify the non-dimensional explanation for which it is a disguise. It is a very variable thing, and only great mathematical powers could have accomplished the results already achieved by the relativists, especially when non-uniform motion is involved.

There is another characteristic of dimensional explanations which should be emphasized at this point. As they transfer the expression of nature's operations to definitions, the conclusions no longer follow from observation, but are circular, tautological or question-begging, as all propositions are which follow from definition alone.

Compare, for instance, the propositions: (1) No triangle has four sides, and (2) All iron is magnetic. Both of these propositions are true, but (1) is a truism, following from definition alone, whereas (2) is not a truism, but follows from observation and inductive inference therefrom. Thus (1) is certain and undebatable, while (2) is only probable. That is, it is not impossible that a non-magnetic metal of atomic weight 56 and having the other characteristics of iron, might be discovered, but it is impossible that a four-sided triangle might be discovered, since that would involve a contradiction. Now how can a non-truism like (2) be converted into a truism like (1)? Very easily. The proper redefinition will do it. We have only to redefine iron as follows: Iron is a magnetic metal of atomic weight 56. (2) now becomes a truism like (1) and no more debatable. The conclusions of relativity owe their truistic, non-debatable character to a similar process of redefinition. Note, for example, on page 8 that, according to Einstein, the time taken by light to go from *A* to *M* (Fig. 1), is the same as the time

taken to go from *B* to *M*, and that this statement of the equality of the times is not debatable, because it follows from his redefinition of "simultaneity." Using the Newtonian meaning of simultaneity, of course, such a proposition could only be established by observation, and its truth could not be asserted categorically. For another example —this time from derivative magnitudes—note the following statement of Eddington:

"The field laws—conservation of energy, mass, momentum and of electric charge, the law of gravitation, Maxwell's equations—are not controlling laws. They are truisms. . . .

"Energy momentum and stress, which we have identified with the ten principal curvatures of the world, are the subject of the famous laws of conservation of energy and momentum. Granting that the identification is correct, *these laws are mathematical identities*. Violation of them is unthinkable."[2]

How a mathematician can convert such observationally discovered and established laws as those mentioned in this quotation into truisms, with all the certainty of truisms, is a mystery which baffles the relativists themselves, not to mention the non-relativists. But if we will note how the proposition—All iron is magnetic—may be converted into a similar truism, with a similar certainty, the mystery will disappear. It is simply a verbal hocus-pocus—a mere process of redefinition, and the appearance of certainty is a misleading one, since the meaning changes though the words do not. The Newtonian propositions retain only the degree of probability which observation and inductive inference therefrom, provides them. The semblance of mathematical exactitude and freedom from doubt arises

[2]Eddington, A. S., *The Nature of the Physical World*, pp. 236, 237.

from the curious process of redefining the fundamental (and hence the derivative) dimensions in such a way as to make laws of nature appear to depend exclusively upon definition instead of observation. The unity in the operations of the universe which this remarkable unity of dimensional expression is concealing, will appear in later pages. In those pages, in fact, the reader will have frequent occasion to note how these dimensional circles nonplus the relativists, and involve them in contradictions. For though they use the dimensional procedure they evidently do not understand its nature, and hence are almost as badly bewildered by its truistic conclusions as the rest of the world.[3] And here let me emphasize that in directing attention to the confusion of the relativist authorities in following pages no disparagement of their great abilities is implied. As scientists they are pre-eminent. But when, deserting science, they venture into the unaccustomed paths of metaphysics, they fall into the verbal traps which everywhere beset that subject, traps which have earned for metaphysics the name of "a disease of language." In short, by disregarding Newton's warning *Physics beware of metaphysics* they have encountered the pitfalls which the greatest of the philosophers of history have been unable to avoid.

It will probably occur to most physicists that the dimensional method of explaining physical phenomena by applying a dimensional redefinition, is a very blind, back-handed and confusing method. And the prevailing confusion in the realm of relativity confirms this impression. But methods in science must be judged by their fruits. And in the hands of the relativists this method has borne many fruits beside confusion. As for its general

[3]See particularly Chapter VII, Sections 22 and 25.

usefulness—in predicting the lag of light signals or the variation of pendulum swing with latitude, for instance—we may suspend judgment. But it may well be that the extension of this method, especially by those who understand its nature, may have far-reaching consequences, for it is undoubtedly a mathematical instrument of great power in competent hands. I do not propose to speculate about such possibilities. It will suffice for the present to have made clear the distinction between dimensional and non-dimensional corrections and explanations, for it will help us to take the next step in our effort to clear the mystery of relativity—the identification of the magnitude whose relativity with motion has been mistaken for that of time and space.

CHAPTER III

THE ROSETTA STONES OF RELATIVITY

FROM the examples cited in the last chapter it is fairly evident that for every law of variation of phenomena for which a non-dimensional explanation may be given, it is possible, at least theoretically, to formulate a dimensional one. And in every such case *the new definitions of time, length or mass will have explanatory power, because they will be disguises for non-dimensional explanations.* Now our knowledge of the physical world is far from complete; nevertheless it is increasing; and it is quite possible that in the course of its increase, a dimensional explanation of given phenomena may be detected earlier than the non-dimensional one. In the example of the *l*-effect and its explanation, for instance, this might easily have been the case. It is possible therefore, indeed rather plausible, to assume that the theory of relativity presents an example of this character. I propose to adopt such an hypothesis, and by comparison with the facts to test its plausibility. The problem presented, then, assumes this form: Given Einstein's dimensional explanation of a group of physical phenomena: *To find* the non-dimensional explanation. It seems evident at the outset that if we can discover physical effects analogous to the *d*- and *l*-effects, for which both relativist and non-relativist explanations are available, we might uncover a promising clue in the nature of a Rosetta Stone whereby the dimensional language of Einstein might be translated into non-dimensional lan-

guage. And fortunately such Rosetta Stones are discoverable. Let us examine one of them.

It is well known that the classical experiment of Fizeau *in 1851 proved that the velocity of light in a moving material medium is different from its velocity in a stationary one. By comparing the velocity of light through a tube of* water when tube and water are stationary, with its velocity when the water is flowing through the tube, Fizeau, and others after him, found that when the light is propagated in the same direction as the water it moves faster relative to the tube and slower relative to the water, whereas when it is propagated in the opposite direction it moves slower relative to the tube and faster relative to the water. This is the Fizeau effect. The change in the velocity of the light relative to the tube is thus only a fraction of the change in the velocity of the water relative thereto. This fraction is seven-sixteenths. The change is always fractional, but is proportional to the index of refraction of the medium. Zeeman, when repeating Fizeau's experiment, using heavy glass and quartz instead of water as media, found larger fractions. A common explanation of the Fizeau effect is the hypothesis of Fresnel of a partial ether drag in transparent bodies, an hypothesis by which he sought to explain the puzzling Airy experiment on aberration. Fresnel's formula for the Fizeau effect is as follows:

$$(3)\quad V = \frac{c}{n} \pm v\left(1 - \frac{1}{n^2}\right)$$

where V is the velocity of the light relative to the tube when the water is moving at velocity v relative thereto, n is the index of refraction of water, and c is the velocity of light in vacuo. When light and water move in the same direction, the plus sign applies, showing that the velocity

of the light relative to the tube is increased. When they move in opposite directions, the minus sign applies, showing that it is decreased. Lorentz, however, reasoning from the electromagnetic theory of Maxwell, and assuming a stationary ether, arrived at the same result. There are reasons for believing that the Maxwell-Lorentz explanation is the correct one, but it apparently admits of a very simple interpretation to which Lorentz did not call specific attention. Nevertheless, as it will help us find the clue we are seeking, it is important to present it here. This interpretation is nothing new, being little more than the reasoning of Sellmeier and Helmholtz extended to the phenomena of moving bodies.

It is generally recognized that the retardation of light by transparent media receives simple explanation on the hypothesis that the particles of the medium constitute light-loading units which require to be set in vibratory and transient motion by the passing light waves, and that the transfer of energy from the particles and back again thus called for (the energy-exchange) requires time, as all energy-exchange does. Hence the retardation of the light compared to its velocity in vacuo, where no such extra transfer is called for. The theories of dispersion of Sellmeier, Helmholtz and Lorentz all incidentally assume this, the first identifying the light-loading units with molecules, the second with atoms, and the third with electrons. The probability is that the light-loading unit cannot be positively identified with any one of these particles exclusively. It is, however, sufficient for present purposes to assume that the retardation is caused by light-loading units of some kind, perhaps of several kinds, and that the number of these units, other things being equal, is proportional to the density of the medium.

Now it is a commonplace of physics that the structure of matter is not continuous; that an apparently homogeneous medium is made up of molecules separated from one another by empty spaces, these latter having identical characteristics, so far as the transmission of light is concerned, with the ether of the interstellar spaces. The molecules which are separated by these empty spaces are, of course, of different mass for different media, but on the theories of Sellmeier, Helmholtz and Lorentz alike, the loading units are associated with the molecules, and for any given homogeneous medium and any given wave-length, the retardation by a given loading unit will be the same. The movement of a light ray in traversing a given homogeneous medium therefore will consist of a series of discontinuous stages or jumps, between which its velocity will vary. While traversing the loading units it will be retarded (relative to the ether) and while traversing the space between the loading units it will not be retarded, but will move with the same velocity as in any empty space. In an attenuated gas, at least, it is obvious that this must be the case. Its progress may be compared to that of an untiring runner traversing a cinder path, interrupted at regular intervals by zones of soft ground. Such a runner would progress in a series of discontinuous spurts and retardations. He would speed up when traversing the cinder path and slow down when traversing the zones of soft earth.

Suppose now the water in the Fizeau experiment, through which light is moving in this discontinuous manner, is set in motion in a direction coinciding with, or opposite to, the motion of the light waves. On the assumption of a stationary ether, what happens to the light? It is entirely in accord with the Lorentz explanation to con-

clude that, in the space between the loading units, nothing at all happens to the light, but that within them the light shares in the motion of the unit. Thus we do not assume, as Fresnel does, that the loading (material) unit drags the ethereal medium, but merely that it drags the light. We may call this the light-drag or more generally, the radiation-drag, or drift, theory, since there is no reason to infer that this reaction of matter on radiation is confined to the visible wave-lengths exclusively.* It simply makes the natural assumption that moving loading units retard light in essentially the same way as stationary ones and hence cause the light to share in their motion, just as a person walking along the aisle of a moving railroad car shares in the motion of the car, or as a sound wave travelling in moving air shares in the motion of the air.

The interpretation of the Fizeau effect here given indicates that matter and ether are not so different from one another as has been assumed, since, if this explanation is the correct one, the loading unit is as much a carrier of the light as the ether itself. So much for the non-relativity

*The discontinuous movement of light through material media was noted by Michelson and Morley more than forty years ago, and the fractional acceleration imparted to light by the movement of such media attributed to it (see *American Journal of Science,* vol. 81, 1886, pp. 378–79). In fact the theory here presented appears to be identical with theirs except that it assumes that the thing dragged is not ether, but light. The ether here referred to is the ether as assumed by Fresnel, *i. e.*, the medium in which radiation travels, but not itself radiation.

A less simple variation of this explanation is that which regards the retardation of light by loading units as analogous to the retardation of water waves by floating logs which require to be set in motion by the passing waves. On this view the units are not actual carriers of the waves, but merely modifiers of their velocity. No final decision between these interpretations will be undertaken here, though whether the latter could be made to explain transverse drift, as in the Airy experiment, is uncertain. Both interpretations, however, explain the Fizeau effect as due to a radiation displacement, which, after all, is the essential point, so far as concerns the discovery of the physical cause which the relativity definitions are disguising.

explanation of the Fizeau effect. It is obviously an effect caused by the displacement of radiation (light) by moving matter. Let us now turn to the relativity explanation of the same effect.

In Section 13 of Einstein's book, we encounter this passage:

"Now in practice we can move clocks and measuring-rods only with velocities that are small compared with the velocity of light; hence we shall hardly be able to compare the results of the previous section directly with the reality. But, on the other hand, these results must strike you as being very singular, and for that reason I shall now draw another conclusion from the theory, one which can easily be derived from the foregoing considerations, and which has been most elegantly confirmed by experiment."[1]

Einstein then proceeds to refer the reader to two equations of the "Lorentz transformation," namely:

$$(4) \quad l' = \frac{l - vt}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$(5) \quad t' = \frac{t - \frac{v^2}{c^2}l}{\sqrt{1 - \frac{v^2}{c^2}}}$$

In these expressions, v is the velocity of the medium relative to the tube, c the velocity of light when no medium is present, t' and l' the time and length as measured by an observer moving with the water, and t and l the time and length as measured by an observer stationary relative to the tube. Substituting the new meanings of length and time provided by these equations, Einstein obtains the

[1] *Relativity*, p. 38.

following equation for the velocity of light in the medium in Fizeau's experiment:

$$(6)\quad V = \frac{V + w}{1 + \frac{vw}{c^2}}$$

This gives the velocity V relative to the tube, of light, where w is the velocity in the stationary water and v is the velocity of the water relative to the tube. He then points out that this equation applies to the Fizeau effect when the observer is stationary relative to the tube through which the water is moving—and Fizeau, in observing the effect, was thus stationary. This equation, in fact, is in agreement with the observations of Fizeau, Michelson and Morley and Zeeman, and thus, as Einstein says, his explanation is "most elegantly confirmed by experiment." It should be noted, in passing, that formula (6) contains the magnitude w, which is simply $\frac{c}{n}$ and hence depends upon the index of refraction (n) of water. If carbon bi-sulphide had been used in the experiment, for instance, w would have had a different value. This is an instance of the general fact, too often overlooked, that the relativity of time and space, and the associated constancy of the velocity of light, is not concerned with relative motion alone, but is a function of the index of refraction of the medium through which the light is moving. That is, the velocity of light is not really a cosmic constant, but a local one. w in water, for instance, is only about 140,000 miles per second, whereas c is 186,000. Einstein emphasizes this point when he says:

"In accordance with the principle of relativity we shall certainly have to take for granted that the propagation of

light always takes place with the same velocity *w with respect to the liquid,* whether the latter is in motion with reference to other bodies or not."[2]

Having thus made it clear that the relativity (dimensional) explanation is confirmed by the Fizeau experiment, he proceeds to point out that a certain non-relativity (non-dimensional) explanation is confirmed also, for on the next page he has this to say:

"Nevertheless we must now draw attention to the fact that a theory of this phenomenon was given by H. A. Lorentz long before the statement of the theory of relativity. This theory was of a purely electrodynamical nature, and was obtained by the use of particular hypotheses as to the electromagnetic structure of matter. This circumstance, however, does not in the least diminish the conclusiveness of the experiment as a crucial test in favour of the theory of relativity, for the electrodynamics of Maxwell-Lorentz, on which the original theory was based, in no way opposes the theory of relativity."[3]

This confirms the hypothesis proposed at the beginning of this chapter, that Einstein's explanation is a dimensional disguise for Lorentz's. For how could the Fizeau experiment be "a crucial test in favour of the theory of relativity" without being an equally crucial test in favor of a theory, certainly not less specific, which "in no way opposes" it. That the hypothesis is confirmed may perhaps be more clearly seen if we compare the three following statements: (1) Lorentz, in agreement with all classical physicists, asserts that the velocity of the light relative to the liquid (water) is caused to change by the movement of the water relative to the tube. This follows from their agreement that the displacement of the light

[2]*Relativity,* p. 40. [3]*Ibid.,* p. 41.

relative to the tube, caused by the movement of the water, has been shown by experiment to be only a fraction of the displacement of the water relative thereto. (2) Einstein asserts that the velocity of the light relative to the liquid is *not* caused to change by the movement of the water relative to the tube. This follows from Einstein's words, above quoted, from page 40 of his book. (3) The assertion of Lorentz "in no way opposes" the assertion of Einstein. This follows from Einstein's words, above quoted, from page 41 of his book. These three statements can be reconciled on the hypothesis (verified by the procedure of redefinition cited in Chapter I) that Einstein has, by a dimensional procedure, changed the meaning of the word "velocity." But on what other hypothesis can they be reconciled? It is safe to say there is no other. Thus Einstein's theory is not a denial of, nor an alternative for, that of Lorentz. It is only a duplicate and disguise for it. The appearance of opposition between the two theories arises from the double meanings of the words "time" and "length" and hence of their ratio "velocity." But this agreement of the two explanations in the case of the Fizeau effect is of great significance, because it leads to the identification of the real magnitude whose relativity with motion has been attributed by Einstein to a relativity of space and time. *It is simply a radiation displacement caused by the motion of matter.* And this gives us the non-dimensional explanation which corresponds to Einstein's dimensional one. Just what kind of a radiation displacement is involved will become clear in Chapter V, Section 2. It may suffice here to say that it is a kind whose relativity with motion has long been known to classical physicists, and has no more to do with space and time than physical phenomena in general.

The conclusion reached by means of the Fizeau experiment is confirmed by the fact that Einstein gives a similar dimensional explanation of the Doppler effect and of the aberration of light (including the Airy effect), both of which are radiation displacements caused by the motion of matter. These three effects, therefore, constitute veritable Rosetta Stones of Relativity, for in their explanations the mysterious dimensional language of relativity appears side by side with the familiar (non-dimensional) language of radiation displacement, and *all three Stones agree about the translation.*

The clue to the non-dimensional counterpart of Einstein's definitions thus afforded is a most valuable one, since it is *apriori* unlikely that they disguise one kind of physical agency in one realm of physics and an entirely different kind in other realms. The Lorentz transformation, however, which embodies these definitions, is applicable to the physics of moving bodies in general, from electrons to planets. Hence the objection must arise that the non-dimensional explanation applicable to the Fizeau, Airy and Doppler effects, where radiation (light) exists which is capable of displacement by matter, cannot be applicable to non-optical phenomena, such as those of gravitation and electricity, since here no radiation exists which matter can displace. This objection has not been overlooked, nor the difficulty it raises ignored. Despite its implications, however, we shall endeavor to establish a presumption that the translation provided by our Rosetta Stones applies to non-optical phenomena also, and may be used to decipher the whole mysterious language of relativity. For is it not reasonable to infer that the applicability of the relativity definitions to gravitational, electric, magnetic and optical fields alike indicates that gravi-

tational, electric and magnetic fields resemble optical fields more than has hitherto been suspected? It would at any rate seem somewhat likely. Perhaps then further search may lead us to revise certain prevailing assumptions about the constitution of the universe, and to conclude that there may be "more things in heaven and earth" than have been dreamt in our philosophy.

CHAPTER IV

THE RADIATION THEORY

When we look up at the sky on a clear night, the heavens present a spectacle of thousands of points of light, each, as we have reason to infer, representing a star shining far off in space. Of course the star-light thus perceived is not distributed through the universe in isolated beams, as the appearance of the sky might suggest, but consists of spherical shells or wave-fronts of light radiating in all directions, something like an innumerable succession of concentric soap bubbles, expanding outward from the star as a centre, at the prodigious rate of 186,000 miles a second. These moving spherical shells meet and interpenetrate, each proceeding on its way unimpeded by the others, so that interstellar space, though devoid of matter, is filled with innumerable moving spheres of radiation, each centred in a separate star, which, so far as we can discover, radiates into space an amount of energy many millions of times greater than it receives from the radiations of other stars.

When we sit quietly in a room of even temperature, we are immersed in an atmosphere of air, consisting of countless millions of molecules, each of which resembles a star in being a centre of radiation. This (heat) radiation, of a wave-length too great to affect the eye, is nevertheless of the same general character as that which proceeds from the stars and travels through space at the same rate of speed. It expands in a similar succession of concentric spherical shells which meet and interpenetrate

in the space of the room as the spheres of star-light meet and interpenetrate in interstellar space. The molecules, however, differ from the stars in that they receive on the average as much radiation as they emit; that is, the radiant energy is in a constant state of exchange or dynamic equilibrium, each molecule giving to its fellow molecules throughout the room as much radiation as it receives from them, and thus the temperature remains constant. This suggests to us another and a slightly different picture of the situation which obtains in the space around us. Let us hold it within call a few minutes while considering some facts which science has ascertained about this radiating habit, seemingly so persistent in the universe.

In the first place, every particle of matter known to science has the radiating habit. An assemblage of molecules at the absolute zero of temperature to be sure would theoretically cease to radiate, but science has never encountered such an assemblage. Indeed there is no evidence that the universe contains matter in this condition.

In the second place, the velocity in vacuo of all radiations, irrespective of wave-length, is the same.

In the third place, there are reasons for believing that all radiation impinging on a given particle of matter and reflected, absorbed, or otherwise re-radiated by it, exerts a pressure upon it (the light pressure), the degree of which depends upon the amount of radiant energy per unit of volume, and upon the capacity of the particle to re-radiate it. This pressure was predicted by Maxwell, and first measured by Lebedew, Nichols and Hull.

In the fourth place, the capacity of matter to reflect or absorb light and thus receive pressure from it, varies according to the dimensions and state of aggregation of the

particle, and the wave-length or frequency of the radiations which impinge upon it. This variation is irregular, but among the shorter wave-lengths, such as those which include the X-rays, the rule seems to be that the shorter the wave-length the more penetrating it becomes, so that, among wave-lengths of this class, the reflecting and absorbing power of matter per molecule diminishes as the wave-length diminishes.

In the fifth place, the pressure exerted by radiation—the radiation pressure—tends to cause matter to accelerate in a direction coinciding with that of the wave-front at the point of impingement.

Now by far the greater part of the radiation familiar to science is a function of temperature. The higher the temperature of a body, the more intensely in general it radiates, and the shorter becomes the average wave-length of the radiation. But this relation between degree of radiation and temperature is not universal, and there is at least one kind of short wave radiation known to science which is independent of the temperature of the source—the gamma radiation from radium. On first thought it would appear that this sort of radiation is probably exceptional and plays a minor part in physical phenomena, since the radiation dependent upon temperature appears so much more universal in nature. On second thought, however, some doubts may arise. What appears to man to predominate in nature will depend, in part at least, on his capacity to observe, and we may surmise that his capacity to observe light and heat may be much greater than his capacity to observe various other radiations, which may nevertheless exist. Since radio broadcasting has become common, for instance, the rooms of our houses are filled with all kinds of strange radiations

—vast potentialities of sensation—which we should never suspect did we not possess radio receiving apparatus which extends our powers of detecting radiation—and this radio radiation, by the way, is another kind that is independent of temperature. Perhaps, then, radiation depending upon temperature—thermal radiation—appears to predominate over the non-thermal kind only because of the predominance of man's capacity to detect that particular kind of radiation.

But it may be objected that if non-thermal radiation is a habit of nature as universal as thermal, we should at least expect to notice its effects all about us, even if we are unable to detect the radiation itself, and where are such effects to be noticed? Well, we cannot give any sure answer to this question, but we may hazard a guess that perhaps we are continually witnessing effects of such radiation without realizing the fact. At any rate we are continually witnessing effects the causes of which we do not know. What causes an apple to fall to the ground? What causes the moon to move about the earth in the peculiar manner in which we observe it moving, or the earth to revolve around the sun? We say it is the force of gravity, but what is the origin of the force? We know the law of gravity—the familiar inverse-square law discovered by Newton—but we do not know its cause. We know *how* it acts but not *why*. Similarly, what causes one billiard ball to move when another strikes it, or one piece of matter in general to resist the movement of another in contact with it? We say it is due to the impenetrability of matter, but again this word expresses no more than the general fact of impenetrability. It does not tell us *why* matter is impenetrable, nor does it inform us why the various attracting particles of the universe cannot, or

at any rate do not, coalesce into one. Particles of matter seem to attract one another at a distance, but repel one another at close quarters. Here is a rather strange contrast, or at least we should be likely to think it one if we were not so accustomed to it. Not only gravity and impenetrability but adhesion and cohesion illustrate this persistent habit of material particles to attract and yet repel one another.

Still again, consider the great variety of electrical and magnetic effects familiar to science, the attractions and repulsions of statically charged bodies, of electric currents and of magnetic poles. Here is a bewildering variety of phenomena concerning which we know much of the how but nothing of the why. And lastly in chemistry, even in sub-atomic chemistry, the scientist is confronted with attractions and repulsions and variations thereof wherever he turns, the causes of which are unknown. They are to be sure called "chemical affinities" or the like, but of course their name tells us nothing of their nature. Thus the chemist, like the physicist, can do no more than cover up his ignorance with a name. Yet the fact that all these various effects, chemical, physical and cosmical, are characterized by attractions and repulsions—always attractions and repulsions—suggests that there may be something common to their causes. Can some kind of non-thermal radiation prevalent in the universe have something to do with it? We know from observation that nature appears to be partial to radiation from centres—she seems to have this sort of radiation habit. And we also know from observation that these radiations by their pressure can, and do, produce repulsions, and by their differences of pressure (and perhaps in other ways) are capable of producing attractions. Can it be that the vast

variety of changes going on in matter all about us can be effects of such causes? It would seem as if we were at least entitled to suspect it. In order that we may speculate to some purpose about these subjects suppose we consider another class of pertinent phenomena.

The light from the stars reaches us after traversing the vast regions of interstellar and apparently empty space, and that light consists of undulations of some kind is attested by a great variety of evidence. But if space is really empty what is it that is undulating? Can it be some sort of nothing? If so, why does light travel at such a definite and finite velocity? Can "nothing" vibrate? And if so, why should it select this particular velocity with which to transmit its vibrations, rather than an infinite velocity for instance? The chances are that this velocity is not an arbitrary unconditioned constant of the universe, but like other finite things, depends upon causes. Light in fact acts suspiciously like a wave motion travelling in a medium of some kind and interchanging energy with it at a finite rate. Its analogies to sound and other wave motions are unmistakable. Hence physicists have assumed that space is not really empty, but is filled with a medium of some kind—the so-called luminiferous ether—bearing some resemblance to matter as we know it. This ether to be sure must be a very peculiar kind of matter—if we want to call it such—possessed of very extreme characters. Clerk Maxwell calculated its density to be only 936×10^{-21} that of water and its viscosity only 10^{-9} that of steel. These extreme, not to say grotesque, properties have caused many modern physicists to become disgusted with the notion of this hypothetical ether, and there is a strong tendency among them to deny its existence. This feeling of incredulity is very natural. Reasonable men are reluc-

tant to assume the existence of strange and unfamiliar things in the universe unless they are forced to it. But if they deny the existence of the ether they are rather forced to assume undulations in nothing, and this is something more strange and unfamiliar than an ether. Moreover, they are forced to assume that the peculiar kind of nothing which constitutes space is at least an energy-containing and conveying nothing, in which dwell manifold gravitational, optical and magnetic "fields" in a constant state of change, for the evidence that such energy changes are transmitted from star to star throughout the universe is overwhelming. So, as a choice between evils, physicists have usually assumed an ether. Yet after all why should we suppose that the limitations of our experience accurately represent the limitations of the universe? Our view of reality is narrowly conditioned by our powers of perception and may be very one-sided. And besides, there is the light of the stars—an undoubted wave motion—what are we to do with this stubborn fact?

At any rate, I am going to venture to go entirely contrary to the trend of much modern speculation about the ether, and not only assume its existence, but assume that it resembles the kind of matter familiar to us even more than has heretofore been suspected. I shall assume not only that it consists, like ordinary matter, of very minute particles of some kind, much smaller than atoms or electrons (which is no new assumption), but that these particles, like all other particles of matter known to science, are centres of radiation expanding outward with the speed of light, just as radiations from stars and molecules do, and that this ethereal radiation, like all other radiation known to science, exerts a pressure on any particle capable of re-radiating it. This I take to be a somewhat new as-

sumption—at any rate it does not commonly prevail among physicists—but it leads to some rather interesting conclusions, so let us elaborate it a little further.

The ethereal radiation assumed to pervade space by the radiation theory thus suggested, must be of extremely short wave-length and hence high frequency. In fact it must be vastly "harder" than the hardest X-ray—of a hardness indeed of a different order—penetrating metals of the greatest density much as sun-light penetrates the attenuated layers of the earth's atmosphere. Recent discoveries have made the existence of such powers of penetration less unlikely than formerly. Atoms appear less solid than was heretofore supposed. Russell says: "The earth, . . . solid as it looks, is mostly empty space."[1] Eddington tells us that—"The ether can slip through the atoms as easily as through the solar system."[2] And these statements are rendered entirely plausible when we contemplate the picture presented by Graetz:

> "If we suppose . . . that the atom (whose order of magnitude is 10^{-8} cms.) is magnified so that it occupies the volume of the earth, of radius 6350 kms., then the nucleus of the hydrogen atom will have a radius of only 6 cms. corresponding thus with about the size of a child's ball, while a negative electron at the same magnification, corresponds with the volume of a large church, its radius being 120 m."[3]

Even assuming the nuclei and electrons themselves are impenetrable to all radiations, which would appear improbable, it is obvious that such a structure as this would not cause much of a shadow effect on ethereal radiation.

[1]Russell, Bertrand, *The A B C of Relativity*, p. 125.
[2]Eddington, A. S., *The Nature of the Physical World*, pp. 3, 4.
[3]Graetz, L., *Recent Developments in Atomic Theory*, p. 78.

Not only has it been shown that the structure of matter is much more open than formerly supposed, but radiation of greater and greater penetrating power is progressively revealing itself to science. The so-called "cosmic rays" on which Millikan and other physicists have been working, for instance, have been found to penetrate some sixteen feet of lead. Jeans, indeed, goes so far as to assume that some of these rays near the point of their origin are capable of penetrating the bodies of nebulæ, thus traversing matter which in quantity, though not in density, is perhaps the equivalent of what would be encountered in passing through a star, or even more than one.[4] And Deslandres has given evidence of radiations proceeding from the interior of stars so penetrating that they "are able to reach from the centre to the atmosphere, and even outside the star altogether."[5] So that in assuming radiation of the character herein specified, I am not departing so very far from inferences already familiar to physics.

But if a super-penetrating ethereal radiation exists which by its power to push can cause repulsion, and by differences in its pushing power can cause attraction, the possibility begins to emerge of explaining many hitherto mysterious things about physical and chemical phenomena, in which the pushings and pullings, the repulsions and attractions, of material bodies, from suns to electrons, are about the most conspicuous features open to our observation. In chemistry this sort of reaction of bodies upon one another is more disguised than in electricity and magnetism, but the more we learn about the smaller units of matter, the more their resemblance to that of suns, planets, magnetic poles and charged pith balls forces itself upon

[4]*Nature,* Dec. 4, 1926, Supplement, p. 39.
[5]Dingle, H., *Modern Astrophysics,* p. 220.

our notice. Let us then venture on a provisional guess to this effect:

All change in the motion of material bodies relative to the ether is the result of differences in the radiation pressure effectively impinging upon them, and all absence of change in their motion is the result of absence of such differences.

We may also venture on a quantitative statement, as follows:

The amount of change of motion (change of momentum) is proportional to the amount of difference in effective radiation pressure multiplied by the cosine of the angle of incidence of the impinging radiation.

Of course the radiation referred to in these statements is that which is re-radiated—in other words, interchanged—by the body. If the pressure resulting from this interchange is the same in all directions, there is no change of motion. If it is not the same, change of motion results, and the direction of change is that of the greater pressure as determined by the familiar parallelogram of forces. The amount of radiation re-radiated by a material body—whether sun or electron—will depend, in the first place, upon the proportion of its mass subject to impingement, in the second place upon the intensity of the impinging radiation, and in the third place upon the capacity of the body to re-radiate the particular kind of radiation impinging. Here are three variable factors, the combination of which with the vast variation of kinds, intensities and directions of radiation which apparently occur in the universe is bound to result in a stupendously complicated assemblage of motions—the sort of assemblage in fact that nature presents to our observation.

Condensing these considerations into something in the

nature of a picture, we may perhaps represent the assumptions of the radiation theory by comparing space to a *very large room filled with air at constant temperature.* In such a room the air molecules will be exchanging radiation with one another through the empty space which separates them. Individual molecules will constantly vary their speed, as they approach and recede, or collide with, one another, but the average velocity of the molecules throughout the room will remain the same because the temperature is constant. From each molecule in such an aggregation will proceed a succession of waves of radiant heat expanding outward with the velocity of light, and hence the sum total of the radiation thus pervading the room and moving in all directions will produce an effect of a radiant space or ether. That is to say, each portion of inter-molecular space, equivalent in volume to a molecule, will act as a centre of radiation, as much as if it were actually occupied by a radiating molecule. This is the picture presented to us by the kinetic theory of gases, accepted generally by physicists. The radiation theory does little more than expand the size of the room to the (unknown) dimensions of the universe of space in which our earth happens to find itself, and increase the frequency of the radiation to the point (also unknown) required by the inertial and gravitational facts of physics. Whatever degree of super-penetration is required by these facts, that degree is assumed by the radiation theory. For the first requirement of any reasonable theory is conformity to fact. That is why, for instance, the theory of evolution assumes a rate of evolution of organisms conforming to the facts, whatever they may be, revealed by the study of historical geology. Strictly speaking, the analogy thus presented would apply only to those portions of space oc-

cupied by material particles corresponding to molecules, since we have no sufficient reason to infer that non-material space is composed of anything analogous in all respects to molecules; and certainly we know nothing of relative motion among the "particles," as I have ventured to call them, of which non-material space is assumed to be composed. Portions of space not occupied by material particles would be the analogue of a room of the characteristics described, were the molecules to disappear—converted into radiation perhaps—leaving a space occupied by radiation alone. The radiation theory, however, assumes that among the existing constituents of matter are very small particles adapted to respond to the super-penetrating radiation thus postulated, as electrons, atoms and molecules respond to lower frequencies, and to any one of these particles the name "materion" will be assigned. The size of materions is also unknown, but it must be very small—much smaller than that of electrons. Nor does the radiation theory assume to know whether materions are of exactly the same size, or only approximately so, though from the analogies presented by larger particles, the latter hypothesis would seem the more probable. Furthermore, the mechanism of the postulated super-penetrating radiation—whether continuous or discontinuous, for instance, or a mixture of the two—is also left doubtful. And this doubt is left in the theory because it is required by the facts; indeed physicists are doubtful in the parallel case of the molecules and molecular radiation comprising the air of a room at constant temperature. The mechanism in the more familiar case is still unknown, and this being so, we shall not assume more specific knowledge in the analogue postulated by the radiation theory. In fact, no attempt is made by the radiation theory, at this stage of its

development, to extend knowledge of the nature of radiation itself. It is simply assumed as the cause of change of material motion without any attempt to explain just what its nature is, or by what precise mechanism the change is brought about. These mysteries of physics remain mysteries.

Two other points, however, remain to be decided: First, is a materion the analogue of a transparent particle, like a piece of glass, or an opaque one like a piece of carbon? The evidence appears to indicate that it resembles a piece of glass, and we shall so assume. That is, we may regard it as the analogue of a very small transparent particle in a field of light moving in all directions, transmitting much more radiation than it absorbs or reflects. Second, is a materion a reflecting, as well as an absorbing and transmitting particle? Lack of evidence does not permit us to answer this question, but, for simplicity, we shall assume, that if it is a reflecting particle we may for present purposes, neglect the radiation which it reflects, and regard it solely as a transmitting, absorbing and radiating body, though we shall not necessarily assume that it re-emits all absorbed radiation in exactly the same form in which absorbed.

These assumptions of the radiation theory will be elaborated and modified as we proceed, but as a preliminary formulation, we may for the present rest satisfied with the picture thus presented. It may here be emphasized, however, that the radiation theory, as expounded in this volume, pretends to be no more than an imperfect fragment of the truth. It is over-simplified, incomplete, and doubtless wrong in many respects. Indeed, it can hardly be otherwise, since the available evidence is far from complete, and the difficulty of inferring from that which is

available, by no means small. Nevertheless, it appears to be an improvement on the theory of a static space at present prevailing, as well as a promising clue to many of the mysteries of modern physics, and this is the justification for its presentation. That space is pervaded by a field of thermal radiation moving in all directions is a commonplace of astronomy. That it is also pervaded by a non-thermal field of the same general character, but much shorter wave-length, is only an assumption. But it is an assumption which may be put to the test, and in the chapter following we shall proceed to test it.

CHAPTER V

QUESTIONING THE RADIATION THEORY

It is the design of the questions raised in this chapter to bring out the main successes and failures of the radiation theory as a means of explanation and prediction. The failures are as important as the successes, and both are to be encountered. Endeavor will be made to present the evidence, favorable and unfavorable alike, so that the facts may speak for themselves. It is to be understood, of course, that there is nothing final in the answers given. They merely represent conclusions which appear to follow from the theory in its present undeveloped condition, and for the most part, are qualitative only. More critical examination of the explanatory power of the theory would probably lead to modification of these answers, or some of them, and to either an increase or decrease of the presumption of its soundness. In many of the answers comparison with conclusions which have been derived from the theory of relativity will appear. The questions follow:

Section 1. What is the cause of gravitation?

Material space (matter) evidently differs in several ways from non-material, or so-called "empty" space. Its universal characteristics have long been recognized as three, namely, gravitation, inertia and impenetrability. To explain gravitation on the relativity theory we shall assume that the radiation emitted by materions is not exactly the same in character as that absorbed, but through some process subject to conjecture, but akin to fluorescence, a small fraction of the in-falling radiation is re-radiated in a form less pressure-producing than that which is re-

ceived. This we may call *G*-radiation, while to the much greater amount re-emitted in the same form as received, we shall assign the name of *I*-radiation. Such change in the character of radiation in the process of being re-radiated is familiar to physicists—in the phenomena of fluorescence and calorescence, for instance—and hence is an assumption which does no violence to our experience. We may also plausibly assume that the diminished pressure-producing power of *G*-radiation is due to the fact that it is less absorbed by materions than ethereal radiation in general, though this perhaps is not a necessary assumption. And finally we may assume that *G*-radiation is very gradually re-converted into normal ethereal radiation in the course of its propagation through space. These assumptions, which here may appear somewhat arbitrary, will in Section 12 be given a less arbitrary form. For the present we may consider how material bodies would react upon one another on the assumptions postulated.

A mass of materions, such as the earth, if alone in space, would, according to the radiation theory, be subject to ethereal radiation pressure on all sides equally. The pressure from the ether surrounding it, being the same in all directions, there would be no preponderance in one direction more than in another, and this would be true of any other isolated mass, whatever its size, even if reduced to that of a single materion. In such a system there would be no tendency to change of material motion. But should another material body (mass of materions), as for instance the moon, be brought into the vicinity, the portion of space occupied by such a body would then be subject to a deficit of effective ethereal radiation proportional to its *G*-radiation, and hence to the mass of the body. Any neighboring body, such as the earth, therefore, would be

subject to an unbalanced radiation pressure, the deficit being on the side next the moon. The presence of the earth would cause a like effect on the moon, and the resultant of the unbalanced radiation pressures would cause the two bodies to tend to approach one another, in other words, to attract one another, the force of the attraction being directly proportional to the mass of each of the two bodies, and therefore to the product of their masses, and inversely proportional to the square of the distance between their centres of gravity, because the mass is proportional to the number of materions, and each unit of deficit of effective radiation follows the inverse-square law common to all radiation from centres. This, of course, is the familiar Newtonian law of universal gravitation. In short, the apparent pull of gravity is, according to the assumptions of this form of the radiation theory, a *disguised push, the motion or tendency to motion, being caused by radiation pressure in an unbalanced condition,* the lack of balance being due to the decreased pressure-producing power of *G*-radiation over ethereal radiation in general.

The most obvious objection to this method of explaining gravitation is the alleged velocity thereof. Laplace, for instance, informs us that:

> "*We must suppose that the gravitational fluid has a velocity which is at least a hundred millions of times greater than that of light. . . . Therefore mathematicians may suppose, as they have heretofore done, that the velocity of the gravitating fluid is infinite.*"[1]

Since the time of Laplace, astronomers, relying on his calculations, have proceeded on the assumption that the

[1]Laplace, P. S., *Mécanique Céleste,* Translation of Nathaniel Bowditch, vol. 4, p. 645.

velocity of gravitation is infinite, and certainly if this assumption is true the radiation theory's explanation of gravitation, as above formulated, must be untrue. But if the radiation theory is refuted by Laplace's conclusions, then the relativity theory is refuted also. We shall see that these two theories have many points in common, and here is one example. Now the interesting feature about this apparent refutation of the radiation theory is that, on examination, it appears to be a confirmation of it in disguise. The fact is that in comparatively recent times, mathematicians have shown that Laplace's conclusion concerning the velocity of gravitation was mistaken. Heaviside, for example, tells us that the "old idea that the speed of gravitation must be an enormous multiple of the speed of light . . . is only moonshine,"[2] and Eddington says:

"The velocity of light being a fundamental relation between the measures of time and space, we may expect the strains representing a varying gravitational field to be propagated with this velocity. We shall show how to derive the equations exhibiting the propagation."[3]

He then proceeds to derive the equations, and after pointing out a certain compensation effect, which the earlier mathematicians had failed to note, he proceeds:

"It was lack of knowledge of this compensation which led Laplace and many following him to state that the velocity of gravitation must far exceed the velocity of light."[4]

Confirmation of this dictum is furnished by Einstein, for the action of gravitation has always been considered

[2]Heaviside, O., *Electromagnetic Theory*, vol. 3, p. 144.
[3]Eddington, A. S., *Report on the Relativity Theory of Gravitation*, p. 67.
[4]*Ibid.*, p. 70.

as the most typical example of alleged "action at a distance," and Einstein tells us that:

"The success of the Faraday-Maxwell interpretation of electromagnetic action at a distance resulted in physicists becoming convinced that there are no such things as instantaneous actions at a distance (not involving an intermediary medium) of the type of Newton's law of gravitation. According to the theory of relativity, action at a distance with the velocity of light always takes the place of instantaneous action at a distance or of action at a distance with an infinite velocity of transmission."[5]

Previous to Einstein's theory of gravitation, Laplace's error had been noted independently by various physicists. Thus Cunningham says:

"This [that Laplace's conclusion is invalidated] was perceived to be the case as soon as the conception of an electro-magnetic constitution of matter was foreshadowed. Weber, Riemann, Levy, Lorentz, and Gerber each suggested modifications of the law of gravitation for moving bodies, which reduce to the Newtonian law when the velocities of the attracting bodies are neglected. . . . Each of these writers assumes a velocity of propagation equal to that of light."[6]

Thus the objection originating in the statement of Laplace is converted into a confirmation, since if Einstein and other modern mathematicians are correct in asserting that gravitation is propagated with the exact velocity called for by the radiation theory, that theory is, in corresponding degree, verified.

It may be noted in passing that the radiation theory

[5]Einstein, A., *Relativity*, p. 48.
[6]Cunningham, E., *Relativity and the Electron Theory*, p. 82.

lends no support to the assumption of action at a distance. That a cause operating in one part of space can produce effects in another part without affecting any intermediate region connecting them is, in view of man's experience with the association of cause and effect, unlikely. It is not to be sure a logical impossibility, since it involves no contradiction, but it is in all probability a physical impossibility. This agrees with the theory of relativity. Indeed, in another place, Einstein informs us that:

"The entire development [of the theory of relativity] starts off from and is dominated by the idea of Faraday and Maxwell, according to which all physical processes involve a continuity of action (as opposed to action at a distance)."[7]

This is stated even more specifically by Schlick, who says:

"According to it [Einstein's law of gravitation], events at one point in the space-time manifold depend only upon the events at points infinitely near it on all sides, whereas in Newton's attraction formula gravitation occurs as a force acting at a distance."[8]

If this interpretation of Einstein's law is correct, the radiation theory and that of relativity are in agreement on this question, except that the former theory suggests the kind of "events" whose occurrence results in gravitation, whereas the latter seeks to reduce gravitation to a static geometric condition of some unimaginable if not causeless kind, which it seems impossible to understand. Despite Schlick's assertion, there seem to be no "events" asso-

[7]Einstein, A., *Nature*, vol. 106, p. 782.
[8]Schlick, M., *Space and Time in Contemporary Physics*, p. 64.

ciated with this condition. It is completely static, yet is something "propagated" with a finite velocity, and yet more strange, propagated with a velocity exactly the same as the very dynamic kind of something familiar to us as light and other radiation, which consists of many "events." *If this identity of velocities is a casual coincidence, it is* perhaps the strangest one known to science. But if, as Einstein asserts, "all physical processes involve a continuity of action" with the velocity of light, the radiation theory renders the coincidence entirely intelligible. According to most, and perhaps all, relativists, however, this "action" takes place without anything "acting," which not only leaves the coincidence unexplained, but leaves the action unexplained also. According to the radiation theory the coincidence of velocities is due to the fact that gravitation is caused by radiation and hence naturally moves with the velocity thereof. It is simply the effect of unbalanced radiation pressure arising from the *G*-radiation emitted by matter.

Lorentz has investigated the theory of the cause of gravitation which follows from the radiation theory, viewing it as an electromagnetic variation of the corpuscular theory of LeSage, dating back to 1764. And his conclusions agree with those here set forth. For, speaking of the energy of the assumed ethereal radiation, he says that his expression "will represent an attracting force . . . if more energy streams through the sphere [of matter] inwards than outwards, and therefore if [the matter] absorbs the rays."[9] Moreover, the expression referred to shows that the attracting force follows the Newtonian law of gravitation. As fluorescence is the equivalent of absorption, and as the *G*-radiation is assumed to be proportional to

[9]Lorentz, H. A., *Lectures on Theoretical Physics*, vol. 1, p. 155.

the fluorescence, it is plain that the assumption of absorption agrees with that of the radiation theory, the only difference being that Lorentz's assumption would require less energy to be re-radiated than absorbed, which would violate the first law of energy, whereas the radiation theory simply assumes less pressure-producing power to be re-radiated than absorbed, which violates neither law nor familiar experience, and yet would cause the same physical effects, since it is the pressure-producing power of the radiation which enables it to cause change of motion in material bodies. Hence if Lorentz's conclusions are correct, the radiation theory of gravitation rests on a secure mathematical foundation. But Lorentz postulates the radiation theory only as a variation of LeSage's theory, and gives it but brief attention. He therefore misses its cosmic significance. For its explanation of gravitation is but one, and rather a weak one, of the explanations which it affords of phenomena hitherto inexplicable. And it is the remarkable and unforced dovetailing of these explanations in widely separated realms of physics which provides the strongest evidence of its soundness. Let us therefore turn to a very different aspect of the radiation theory—its power to explain the physical significance of the relativity equations, both special and general.

Section 2. For what are the equations of relativity, showing deviations from classical laws, dimensional disguises?

According to the radiation theory, these equations are dimensional disguises for Doppler-displacements caused by the motion of material particles relative to the ether, and hence are functions of the rate of motion of said particles relative to one another; because the motion of any

two material particles involves motion of one or both relative to the ether, just as two bodies in a room filled with undisturbed air cannot move relative to each other unless one or both move relative to the air. This interpretation of the equations is clearly foreshadowed in Chapter III, and, as there shown, is unmistakably verified in the case of the Fizeau, Airy, and Doppler effects. Such verification is possible because, in these special cases, the waves displaced are of a readily recognizable kind of radiation, namely, light. The radiation theory simply extends this interpretation to ethereal waves, and their re-radiations from material particles. It is the emission of such radiation from material particles, in fact, that explains the application of the relativity equations to gravitation and inertia; for if such emission occurs, then motion of particles will cause Doppler-displacements in it, and hence dimensional disguises for these displacements will be found to apply. The reason for the surprise of the classical physicists when "relativity" deviations were discovered in their laws was because they did not suspect such emission, and hence did not suspect the deviations from classical laws which would necessarily be caused by it. Ample evidence that material particles emit waves of non-thermal origin will be provided in Sections 4 and 5. The displacements referred to in this section do not alter the velocity of the waves relative to the ether after they leave the source any more than in the analogous case of sound waves.

In order to present evidence that the above answer to the question propounded in this section is the correct one, we may follow up the interpretation of relativity effects provided by the Rosetta Stones of the third chapter, by inquiring more minutely into the resemblance between such

effects and Doppler-displacements. Then, if relativity effects are dimensional disguises for such displacements, they will:

(1) Be confined to phenomena associated with the relative motion of bodies—and they *are* thus confined.

(2) Be a maximum in directions coinciding with the direction of motion—and they *are* a maximum.

(3) Be zero in directions at right angles thereto—and they *are* zero.

(4) Diminish from a maximum to zero through intermediate directions at a rate determined by the cosine law —and they *do* diminish at that rate.

(5) Approach zero as the velocity approaches zero— and they *do* thus approach zero.

(6) Approach infinity as the velocity approaches that of radiation—and they *do* thus approach infinity.

(7) Reverse direction when the velocity exceeds that of radiation, so that "time" appears to run backward, and thus effect to precede cause—and they *do* thus reverse direction.

(8) Be relative to the motion of an observer observing by means of signals or causal impulses moving with the velocity of light—and they *are* thus relative.

This eighth coincidence is particularly suggestive, since a relativity dependent on motion is obviously a fundamental characteristic of Doppler-displacements when observation is made by means of signals moving with the velocity of the waves subject to such displacements—and by definition an Einsteinian observer always observes by means of light waves. Thus an observer who notices the changed pitch of a moving locomotive whistle is not any observer in the train drawn by the locomotive. It is always an observer relative to whose ears the train is moving; indeed

the pitch can be altered in any manner we please by changing the relative velocity of the observer—a process which the relativist expresses by the phrase "changing the 'frame of reference' or 'co-ordinate system.'" The virtual admission by Eddington that "relativity effects" are due to "Doppler's principle" will be found in Chapter VII, Section 18 (see foot-note, page 205), where his explanation of the "relativity" of color is quoted. The explanation there given of the relativity of color by means of Doppler's principle applies unchanged to the relativity of pitch in musical sounds, and this could not be the case if the relativity effects referred to were something peculiar to light, as the relativists allege.

Again, consider the following statement of Jeffery:

> "Simultaneous and the words before and after, as applied to two instants of time at different points of space, have no precise scientific meaning apart from a specified frame of reference."[10]

Now it is obvious that Doppler-displacements, whether in sound or light waves, "have no precise scientific meaning apart from a specified frame of reference" when observed by means of signals moving with the velocity of the waves themselves, because they must vary with the motion and position in space of the observer. Hence if such displacements thus observed are dimensionally transferred to time and length units in the manner described in Chapter II, then, of course, this same lack of precise meaning will be transferred to the words before, after and simultaneous, just as Jeffery maintains.

Here then are eight correlations which can hardly be

[10]Jeffery, G. B., *Relativity for Physics Students*, p. 29.

accidental, but they constitute only a fraction of the evidence. For if relativity effects are disguised Doppler-displacements then they must be functions of other things than the relative motion of bodies—because Doppler-displacements are. Do relativity effects follow Doppler-displacements in their deviations from the simple relativity with motion represented in the Lorentz transformation? We shall find that they do. They follow them so closely indeed, that when Doppler-displacements become functions of temperature, relativity effects become functions of temperature; when Doppler-displacements become functions of pressure, relativity effects become functions of pressure, and when Doppler-displacements become functions of chemical composition, crystalline structure, etc.—as they often do—relativity effects become functions also, thus departing entirely from any simple dependence on relative motion with its supposed exclusive determination of "space" and "time." To prove this we have only to refer again to Chapter III, page 41, where it will be observed that the velocity of light in vacuo, *c*, which is supposed to be a constant so universal and fundamental as to determine the characteristics of space and time themselves, disappears as a determinant of these magnitudes and is replaced by *w*, the velocity of light in water, because water was the medium in which light was travelling in the Fizeau experiment. Thus the fundamental velocity of 186,000 miles a second is replaced by a velocity of 140,000 miles a second. And what is *w?* It is simply $\frac{c}{n}$ where n is the index of refraction of the medium through which the light is travelling. That is to say, relativity effects are functions of the indices of refraction of bodies and hence functions of whatever such indices are themselves func-

tions of—which means that they depend upon temperature, pressure, chemical composition, crystalline structure, etc., because indices of refraction of transparent media so depend. This seems very mysterious behavior for a determinant of space and time to indulge in. But the mystery disappears when we realize that relativity effects are disguises for Doppler-displacements, for these latter obviously depend upon $\frac{c}{n}$ instead of c alone, and hence on whatever determines n. Thus relativity effects follow Doppler-displacements into dependence on n because they are dimensional disguises for them.

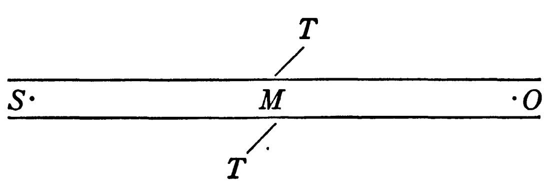
But they follow them still further than to their dependence on n. In Section 18, it will be shown that the Russian physicists, Bélopolski, Galitzin and Wilip produced Doppler effects in light by reflecting it a number of times from rapidly revolving mirrors. The significance of their results as they affect a certain assumption of relativity is considered in that section. At this point their significance in revealing the nature of relativity effects will be dealt with. For if Doppler-displacements can be multiplied by multiplying the number of reflections from a moving body —and the experiments of the Russian physicists prove that, in conformity with classical theory, they can—then another proof that relativity effects are disguises for Doppler-displacements becomes available. For the facts revealed by these Russian experiments either agree with the predictions of the relativity equations or they do not. If they do not, then the equations are refuted by the facts, and hence cannot represent the truth. If they do, then it proves that relativity effects are not dependent on relative motion alone, but are something as arbitrary as the number of reflections to which light is subject, something

that can be varied at the will of the experimenter. In short, they do exactly what Doppler-displacements do, thus following them as closely in their dependence on the number of reflections from surfaces, as on the index of refraction of bodies.

All this circumstantial evidence leaves little doubt about what the relativity definitions are disguising, but as this is a very vital point in modern physical theory, a more complete demonstration will here be given, in fact a deductive one, which appears to leave the matter in no doubt at all. In order to make this demonstration clear, three different kinds of Doppler-displacements may first be distinguished.

Assume Fig. 4 to represent one branch of the tube through which Fizeau in his experiment caused water to move. Let T be the tube, S a source of light attached in any convenient manner to the tube, O an observer in the tube, and M the medium (in this case water) through which the light is moving. To simplify matters we will consider the effects of motion parallel to the tube, ignoring motions at various angles thereto. Now Doppler-displacements may be divided into three kinds, according to whether S, O or M are doing the moving. These kinds are:

Fig. 4



(1) Primary displacements. S moves relative to O and M, but they do not move relative to each other.

(2) Secondary displacements. *O* moves relative to *S* and *M*, but they do not move relative to each other.

(3) Tertiary displacements. *M* moves relative to *S* and *O*, but they do not move relative to each other.

At low velocities of *S*, *O* or *M* compared to the velocity of *light these three kinds of displacement are indistinguishable by ordinary experiments*, and *hence relativity* effects are practical disguises for all three. At high velocities apparently they are only disguises for primary displacements, but only one experiment thus far devised by man is capable of testing the equations of relativity in their application to high velocities. This is the Kaufmann-Bucherer experiment, and the results thereof confirm the statement made above. If slight changes of velocity due to the dispersive character of the medium are ignored, the velocity of the light relative to the medium remains constant in primary and secondary displacement, but the laws of change of frequency and wave-length are different in the two cases, and in Section 18, we shall consider an interesting consequence of this. In the case of tertiary—the kind involved in the Fizeau experiment—this velocity changes in the manner indicated in Chapter III, where it is shown by the Fresnel-Lorentz equation that the change of velocity of the light in the water relative to the tube is different from the change of velocity of the water relative thereto, and hence there must be a change of velocity of the light relative to the water. This change is what determines the magnitude of the Fizeau effect.

To prove that the relativity explanation of this effect is the expression of a tertiary Doppler-displacement, we have only to recall Einstein's own statement, made on page 39 of *Relativity* that the velocity of the water (v) through the tube, in Fizeau's experiment, changes the velocity of

the light traversing the water relative to the tube from w to $\frac{v+w}{1+\frac{vw}{}}$.* From this we may infer that light emitted from S, Fig. 4, which source is by hypothesis fixed relative to the tube, changes its velocity relative to S by the above amount when the velocity of M relative to S changes from zero to v, since the velocity of light traversing the water in the tube relative to the water is the same whether the source is outside the tube, as in the Fizeau experiment, or inside it, as in Fig. 4. But the change of the velocity of light relative to the source emitting it due to the movement of the medium relative to source and observer (which in this case both remain stationary relative to the tube) is by definition a tertiary Doppler-displacement. Hence the change from w to $\frac{v+w}{1+\frac{vw}{c^2}}$ alleged by Einstein to be the change in velocity of the light in the water relative to the tube (and hence to any source of light stationary relative to said tube) is *by definition* the expression of a tertiary

*Both of these velocities, of course, are Newtonian ones. It is instructive, in fact, to notice that the theorem of the constancy of velocity of light relative to all observers, does not hold universally, when the light is traversing a material medium, such as water. It holds only for observers travelling with the medium, since Einstein plainly tells us that the movement of the water relative to the tube causes the velocity of light, relative to observer Fizeau, to *change* in the manner specified in the text. In short, there are no Einsteinian velocities or other magnitudes, except when the observer moves with the medium, because this constancy of velocity principle is what characterizes such magnitudes. Thus when the observer moves with the medium Einsteinian magnitudes appear in the universe. When he does not, they disappear and ordinary Doppler-displacements appear in their place. This is certainly very metaphysical behavior on the part of such magnitudes unless they are the disguises we take them to be. How, for instance, does this replacement of relativity by Doppler phenomena occur when a material medium gradually merges into a vacuum, as the earth's atmosphere merges into the space beyond it? The relativists apparently make no attempt to answer this question.

Doppler-displacement—which was to be proved. In this case, therefore, the evidence that an Einstein equation is a disguise for a Doppler-displacement is not circumstantial but deductive. In short, no other hypothesis is consistent with Einstein's own claim of the change in velocity of the light in the Fizeau experiment relative to the tube, and hence to the source and observer stationary relative to said tube. Thus in the case of the Fizeau experiment the statement that the relativity equations express a Doppler-displacement of strict classical characteristics, is removed from the category of hypotheses. If Einstein's statement is correct, it is a certainty.

But if we discover, in the case of the Fizeau experiment, what the theory of relativity is expressing, we discover what it is expressing when applied to other phenomena, since it is safe to assume that the theory is consistent with itself. That is to say, it is a dimensional disguise for the same thing in one place that it is in another, the so-called "relativity of space and time" being the common explanation of all relativity phenomena. Indeed Einstein is careful to tell us that his special theory of this "relativity" in its entirety, as expressed by the Lorentz transformation, is "most elegantly confirmed" by Fizeau's experiment. In short, he generalizes the confirmation discoverable in that experiment so as to make it a confirmation of his (special) theory as a whole. We are simply adopting his own generalization therefore in concluding that the relativity definitions are disguises for Doppler-displacements, not only in the case of the Fizeau experiment, but in all cases to which the special theory at least applies.

Many facts make it evident that the only deviations from classical laws disclosed by the relativity theory occur in cases where the classical physicists do not recognize

Doppler-displacements. Where they do, as in the Fizeau, Airy and Doppler effects, there is no deviation, and the relativity equations fall into their proper places as expressions of such displacements. The key to the discrepancy will appear in Sections 4–6, where it will be indicated that matter is an emitter of non-thermal radiation unsuspected by the earlier physicists. When this fact is recognized it is readily seen that there is really no need of modifying classical laws. There is only need of recognizing the fact that material particles are radiators, and then the classical laws applying to Doppler-displacements in general will take care of the resulting physical effects, just as they do in the case of the Fizeau, Airy and Doppler effects. In fact the relativity equations take care of them now for the very reason that they are dimensional disguises for these classical laws of Doppler-displacement. Thus there is really no discrepancy between the two theories at all, only the relativists have mistaken the identity of the magnitude subject to relativity, attributing it to space and time instead of to a Doppler-displacement, thus misinterpreting its relativity. But this mistake has effectually concealed the profound and far-reaching truth that matter is a perpetual radiator of non-thermal energy, and hence must be the perpetual recipient of an energy supply which certainly comes from somewhere. If it does not come from a radiant ether where does it come from? Reasons for believing that this is the explanation, not only of the relativity puzzle, but of various other cosmic puzzles, will multiply as we proceed.

Section 3. Why is the theory of relativity divided into a special and a general theory?

The relativist answer to this question would apparently be something like this: If space contained no matter it

would be "uncurved" (some relativists maintain it would not exist). But the presence of matter causes space (or space-time) to become "curved" (some relativists maintain the curvature *is* matter). And this explains (?) gravitation and inertia—which incidentally turn out to be the same thing. The equations of the special theory apply when this curvature, due to the presence of matter, does not exist, in regions, that is, entirely removed from the influence of matter. The equations of the general theory, on the other hand, take account of this curvature, and hence are qualified to express the behavior of nature in gravitational fields. From a perusal of the explanations of many relativists, this is the best guess I am able to make of the relativist answer to the above question. The explanation it conveys is of the usual non-Euclidean type. That is, the "curvature" of space, or space-time, referred to is a purely metaphorical one, suggested by certain analogies.

The answer of the radiation theory is as follows: If the equations of relativity are dimensional disguises for Doppler-displacements, as the hypothesis herein maintained asserts, then the equations which apply to uniform motion will be unlike those which apply to non-uniform, or accelerated, motion, because the Doppler-displacements of the two kinds of motion will of necessity be unlike. But non-uniform motion approximates uniform as the cause of acceleration (force) approaches zero. Hence equations representing uniform motion should be limiting or special cases of those representing non-uniform. Furthermore, when gravitational (or electromagnetic) fields are present, the motion of bodies is in general non-uniform, because the bodies subjected to their influence are accelerated. And when such fields are absent, the motion of bodies is uniform. Hence any dimensional disguise for Doppler-

displacements called for by the radiation theory should be divided into two parts (or theories) according as they are concerned with accelerating or non-accelerating regions of space, and the two theories should be related to one another and to gravitational (and electromagnetic) fields in the manner described.

In accordance with these predictions, the theory of relativity is divided into two parts, the special and the general. The former applies to uniform motion, where no gravitational (or electromagnetic) fields are present to cause acceleration; the latter applies to accelerated motion, where gravitational fields are present, and the former is a limiting case of the latter, as the radiation theory requires that it shall be. Thus the division of the theory of relativity into two theories occurs in the manner called for by the radiation theory, affording additional reason for believing that theory to be sound. In short, the relativity theory divides into two parts because it is a dimensional disguise for Doppler-displacements which divide into two kinds.

The relativists have not yet succeeded in extending the general theory to the phenomena of electromagnetic fields, but are endeavoring to do so. Electromagnetic effects, being very complex, though apparently due to radiational causes, are by no means easy to disguise dimensionally, and this apparently is the source of the difficulty. A corresponding difficulty, due to the same complexity, confronts the radiation theory when its extension to electromagnetic phenomena is attempted, as will become obvious in Chapter VIII.

In following pages it will be indicated that the intuition of Einstein enabled him to successfully foreshadow the radiation theory in outline, including the radiational struc-

ture of matter, but it will also be made apparent that he was by no means the first to foreshadow it.

Section 4. Is matter a form of radiation?

The answer of the radiation theory to this question is of particular importance for two reasons: First, it offers additional evidence that the theory constitutes the sought-for physical explanation of the relativity equations, and second, it leads to an account of the nature of matter, energy and ether, not only in conformity with familiar experience, but devoid of the main difficulties which have hitherto beset the ether theory.

Let us first indicate that an affirmative answer to this question is foreshadowed by the interpretation of the Fizeau experiment set forth in Chapter III. According to that interpretation, matter would seem to be as much a carrier of light as ether. Usually it transmits light more slowly than the ether, but sometimes more rapidly—for indices of refraction are sometimes fractional. This naturally suggests that material particles cannot be so very different from the spaces which separate them, since light travels in much the same way in both. And if the latter are radiant kinds of space, the former are likely to be so also. And what is radiation but a radiant kind of space?

Let us next present evidence that the theory of relativity foreshadows a radiation theory and an affirmative answer to the question here propounded, if indeed it does not require one. Einstein's conclusions about the relation of mass and energy are thus set forth by Haas:

"Einstein found that any body which undergoes an alteration of its energy content must at the same time experience an alteration in its mass. If, for instance, the energy content of a body is diminished by thermal radia-

tion, its mass will also be diminished by an amount which is equal to the magnitude of the energy emitted, divided by the square of the velocity of light. If the energy content increases by a definite amount, say by heating or by the absorption of radiation, the mass will also increase by this amount divided by the square of the velocity of light.

"It was necessary to conclude from this that inertial mass is inherent in all energy as such, and furthermore, that all mass can only have its origin in energy. *Mass and energy* are thus *identical concepts,* and differ only in a proportionality factor. This factor is equal to the square of the velocity of light, and arises from the difference between the measures used. Mass is associated necessarily with all energy, and energy with all mass. Thus the principles of the conservation of mass and the conservation of energy, the laws of Lavoisier and of Mayer, appear united to a *single principle* by the theory of relativity. In spite of this, both laws appear to play an independent rôle, to a very high degree of approximation. The cause of this lies in the infinitesimal smallness of the alterations of mass connected with observable changes in energy."[11]

Now so far as relationship to energy is concerned, mass and matter are equivalent, and it was by assuming the identity of a specific kind of energy with matter that Einstein was led to his prediction of the deflection of starlight by the sun's gravitation, the alleged confirmation of which by eclipse observations first brought his theory into prominence. He inferred that light would be subject to gravitation because, being a form of energy, it must be a form of matter, and hence will be subject to gravitation like other material things. But if light is like matter then matter is like light, and as light is a form of radiation, a presumption arises that matter may be one also. If not, what form of energy is it? Seeking further, we find that

[11]Haas, A., *The New Physics,* pp. 129, 130.

the extension of the law of the conservation of energy to matter, pointed out by Haas, means that when the mass of a body diminishes, energy equivalent thereto must reappear somewhere else, and when it increases, energy previously existing elsewhere must disappear. What form does this appearing and disappearing energy take? Turning for an answer to Richtmyer, we are informed that:

> "According to the theory of relativity, there is a definite equivalence between radiation and matter, such that a definite mass of matter m is equivalent to a quantity of radiation E, according to the equation
> $$E = mc^2$$
> where c is the velocity of light."[12]

And this view of the kind of energy which is equivalent to mass is by Millikan and Cameron expressed thus:

> "If the Einstein special theory of relativity may be taken as a sound basis of reasoning . . . then it follows that radiant energy can never escape from an atomic system without the disappearance of an equivalent amount of mass from that system."[13]

This suggests that the kind of energy which appears when mass disappears and which disappears when mass appears is radiant energy or radiation. Moreover, as we shall see in Section 15, the modern view of the origin of stellar radiation indicates the same transformation. It attributes star-light to radiation originating in the destruction of matter, which suggests the question: If at the moment of disappearance of matter, radiation in a form recognizable (at least by inference) as such appears, what

[12]Richtmyer, F. K., *Introduction to Modern Physics*, p. 544.
[13]Millikan, R. A., and Cameron, G. H., *Scientific American*, vol. 139, p. 136.

is it that has *dis*appeared?. And the most plausible answer would seem to be, "radiation in a form which is not (or has not hitherto been) recognizable as such." In short, the "particle" which was annihilated, was radiation all the time, only it was in a form which our means of observation did not permit us to recognize as radiation. And after all, was it not a long time before men recognized light as such? Even Newton did not perceive its wave-like character. Aston's discovery that when radioactive elements emit radiation, they lose mass in equivalent amount, is another piece of evidence clearly corroborative of this hypothesis. If the concept of matter here suggested then is correct, its destruction (and creation) consists in transforming one form of radiation into another. And obviously, this process has some analogy to fluorescence, though we cannot say how the wave-length changes, if at all. At any rate the radiation behaves differently in the "occupied" or "material" space from what it does in the unoccupied non-material, or so-called "ethereal" space; yet it is still radiation. It may then be rather plausibly assumed that a materion may be no more than a portion of space in which the ethereal energy is different in character from that in the space outside of it. Nor need it be so very different. Perhaps in materions the radiation may be rotational in some sense, analogous, let us say, to a whirlpool. It might, for example, be of the vortex ring type suggested by Kelvin, or of the "rings of Saturn" type suggested by DeBroglie. On the other hand a materion, or even an electron or atom, might be constituted of concentric spherical shells of standing waves caused by re-radiation, perhaps reflection, from a central nucleus of some sort. Einstein has suggested some such idea. Present evidence leaves us only with a choice of guesses to be sure,

but at least it is evident that the concept of matter suggested by the radiation theory is quite similar to that which the modern doctrine of wave mechanics proposes. Biggs, for instance, tells us that:

"A particle is a group of reinforcing waves of slightly differing frequency."[14]

And Flint expresses the same view in the following words:

"The particle is thus to be regarded as a group of waves and the particle velocity is in the wave theory to be interpreted as the velocity of this group."[15]

Again he says:

"The view expressed in the new [wave mechanics] theory is that waves are to be associated with fundamental units of mass like protons and electrons and that these waves have a physical existence."[16]

In yet another place he reiterates this identification of radiation with matter by comparing two equations derived from the wave mechanics and the classical theories of matter respectively, as follows:

"These two equations, which are thus actually the same, represent the motion of a particle, the former describing it as an energy node of a group of waves and the latter describing it as the motion of a massive particle by the classical method."[17]

Confirming the above statements DeBroglie says:

"In the way of looking at the question adopted here . . . the material particle is an essential reality, and its motion

[14]Biggs, H. F., *Wave Mechanics*, p. 67.
[15]Flint, H. T., *Wave Mechanics*, p. 35.
[16]*Ibid.*, p. 26.
[17]*Ibid.*, p. 41.

is completely determined as that of a singularity in the amplitude of a wave which is propagated."[18]

And Davisson tells us, without qualification:

"The evidence that electrons are waves is similar to the evidence that light and X-rays are waves."[19]

For further recently discovered evidence, chiefly experimental,* that matter consists of radiation, see Flint, H. T., *Wave Mechanics,* Chapter 4, entitled "Evidence for the Existence of Mechanical Waves." It is apparent that the wave-length of electrons, as measured by the experimenters cited in this chapter, is not the wave-length of materions or of the ethereal radiation to which they respond. It is a much greater wave-length, of secondary origin. The formulæ expressing Doppler-displacements will be the same whatever the wave-length, since the velocity of radiation in empty space is independent of wave-length. Hence the relativity formulæ, representing such displacements, will apply, no matter what the particle of matter whose movement is involved.

It would seem as if the wave mechanics theory required a radiation theory on which to rest as much as, or even more than, the relativity and the classical theories. On the assumption of a static ether or an empty space, the waves of which its particles are composed are required to be perpetual motion machines, apparently moving around

[18]DeBroglie, L., and Brillouin, L., *Selected Papers on Wave Mechanics,* p. 114.

[19]Davisson, C. J., *The Bell System Technical Journal,* vol. 8, p. 217.

*Cumulative data lead T. J. Johnson to conclude that "from the experimental standpoint an atom is as much a wave as is a quantum of light." (*Journal of the Franklin Institute,* Aug., 1930, p. 152.)

a centre in some manner that waves are never known to move. With a radiation theory all this would change. The atom, or other particle, considered as a wave mechanism, would react in the normal manner of waves. It would not need to be a conservative system in itself, but could radiate freely to space and yet maintain its integrity, being in dynamic equilibrium with its surroundings. Deprived of such resources, indeed, it seems impossible to imagine how an atomic wave structure could act in the slightest degree as radiation is known to act, and yet be in accord with the first law of energy.

Accepted views of matter and energy then strongly imply, in fact some of them explicitly affirm, that the distinction between material and non-material space is no more than a distinction between forms of radiation, and this, as we have seen, is the distinction between matter and ether involved in the assumptions of the radiation theory also. An approach to this view indeed, is suggested by the simplest common sense. Consider, for example, some very plain evidence that the distinction between matter and non-matter is merely a distinction between modes of exchanging energy. Can we, after all, discover by observation or experiment any other distinction between these things? Can our senses even discover any other? If, for instance, a piece of stone exchanged energy with light radiation in exactly the same manner as the space surrounding it, could we tell by our sense of sight which was the material and which the non-material part of space? Or if we put out our hand to touch the stone, and the portion of space occupied by it exchanged energy with our hand in exactly the same manner as the space surrounding it, could we tell by our sense of touch which part of space was occupied by the stone and which was not? I

cannot see how we could. What is the impenetrability of a body but a repelling force which causes a resistance to the motion of another body by virtue of its power to exchange energy therewith, the relative motion of the two continuing until caused by their mutual repulsion to disappear? Clearly it is nothing different. If so, impenetrability as well as gravitation is an energy exchange effect. That it is an effect involving in the last analysis the reaction between matter and radiation is, to be sure, only a speculation, but in view of the sum of the evidence it appears a plausible one. At present physics accepts impenetrability as an empirical fact of energy exchange for which no explanation is forthcoming. The radiation theory suggests something more specific. It suggests that it is a radiation pressure effect, of a conjectural character to be sure, but not necessarily beyond the resources of the radiation theory to account for. Perhaps it is a fluorescence effect resulting in a type of radiation less penetrating than ordinary ethereal radiation, but of an ephemeral character, transmuted almost as soon as produced, back to the normal type. This would result in the exclusively close-quarters repulsion called for. Speculation about the nature of impenetrability, however, can hardly be fruitful with the evidence at present available. More facts are needed about the reaction of radiation on radiation. Further development of the wave mechanics hypothesis and extension of the radiation theory into the realm of electromagnetism may become aids in supplying them. It will suffice here to say that the radiation theory interprets this fundamental property of matter, as it does the other two—gravitation and inertia—as an effect of radiant energy exchange.

In suggesting that, in the absence of any difference in energy exchange effects, matter cannot by any known

physical process be distinguished from non-matter, the radiation theory is proposing nothing unfamiliar to physicists. The only novel suggestion involved is that the energy exchanges by which the distinction is made are expressible exclusively in terms of radiation. But if the energy exchange of matter differs from that of ether only by virtue of the character of the radiation peculiar to the former, then it would appear that what we have referred to as its "fluorescence" is due to the reaction of radiation on radiation. If so, are not all reactions between matter and radiation, reactions between radiation and radiation? The answer is that not only the radiation theory, but the relativity theory and that of wave mechanics, strongly imply it. In fact, this is no more than a somewhat more specific way of suggesting the identity of matter and radiant energy and hence the merging of the laws of conservation of mass and energy into a single law of conservation of radiation. But this, of course, is a quantitative law. It means the amount of radiation in an isolated system, or in the universe, is constant. And how is this "amount" measured? Is it not by the momentum of the radiation? This is certainly one way of measuring amount of radiation. And if this way is selected, the direction as well as the amount is included, as the facts would appear to require. Thus the law of conservation of radiation would include that of the law of conservation of momentum. And this in turn leads us back to some of the earliest speculations on this subject. For what is momentum? It is at least defined as "amount of motion." Hence the law may be regarded as a law of conservation of motion, both in amount and direction, the motion being that of radiation. Experience, however, disposes us to think of motion of all kinds as motion *of* something, and hence we think

of the motion of radiation as the motion *of* something which is not itself radiation. If, however, we are asked how we know it is not, we should be at a loss to say, since it is a familiar fact—in our perception of colors for instance—that radiation may cause sensations without being recognized as radiation. And if it can cause visual sensations, why not tangible ones? What is the motion most familiar to human beings a motion *of?* A motion of matter, to be sure. But matter, as something experienced, is representable in terms of visual and tangible sensation, whose physical associate seems always to be an energy interchange effect. So that the motion of matter would appear to be a motion of energy interchange effects. At least, that seems to be all we can make out of it, even if the radiation and wave mechanics theories are left entirely out of account. These effects, however, preserve their spatial integrity, so to speak. Their motion from point to point in space involves passage through intermediate points in finite time. So far as our experience goes, their disappearance at one point is never accompanied by simultaneous appearance of an equivalent at some distant point. The motion of matter familiar to us is never an action *at* a distance. It is an action *through* a distance. Passage both through intermediate space and intermediate time is required between the appearance of a given body at one point and its appearance at another. And the same is true of any aggregate of radiation. All this of course is highly significant, and highly suggestive of the wave mechanics theories of DeBroglie and Schrödinger. Interpreting them, Biggs says:

" 'The motion of a particle' can be represented by the motion of the region of reinforcement of ψ-waves."[20]

[20]Biggs, H. F., *Wave Mechanics*, p. 24.

And it is plain from the quotation on page 84 that this expression of the wave mechanics theory agrees with DeBroglie's.

If it helps us to think about the subject we may if we please regard the motion of radiation as the motion of some kind of non-radiation, and this non-radiation may be called the ethereal medium. But it seems equally intelligible and reasonable to regard space as so constituted as to be able to support and transmit radiation, without attributing to it a distinct property of non-radiation. However, either concept will do, as long as we realize that two portions of space which cannot exchange energy with one another cannot react with each other, and hence their mutual penetrability will be complete. Each will be an "empty" space to the other. A sphere of lead weighing a ton will be so much empty space to any kind of "particle" which cannot exchange energy with it. The two will pass through one another as unimpededly as the light of one star in the heavens passes through that of another. So far as physics is concerned, then, the ethereal radiation *is* the ether. If this radiation is a motion *of* some kind of non-radiation, we know nothing directly about the latter except that it is a kind of space containing radiation of the character we find there. It is presumably this radiation which constitutes the "fields," gravitational, electrical and magnetic, which both relativists and non-relativists continually refer to. These are modifications of the ether because they are modifications of the radiation which constitutes the ether. Moreover, ordinary light and matter are probably modifications also. This, in substance, is what is meant by saying that the universe is dynamic.

If a more mechanical assumption is desirable, and it would seem to be so, we may find it in the movement of

transverse waves through something analogous to an elastic solid, this solid being regarded as the ethereal medium, a medium through which radiation, ethereal, optical and material (mechanical) alike, is transmitted, the one as unimpededly as the other. This agrees with the view of the nature of impenetrability suggested in this section, and at the same time indicates why (1) material bodies move without retardation through empty space, and (2) transverse vibrations are possible therein. That light is a transverse radiation, and that space reacts to it "as if" it were an elastic solid, are well-known facts. Gases and liquids cannot transmit transverse vibrations. Hence space does not behave like a gas or a liquid. It is plain that of the forms of radiation assumed to occur in the ethereal medium, matter and light are the only ones that reveal themselves directly to the physicist's observation. The dynamic ether, or ethereal field (like the ethereal medium itself) is revealed only through more or less probable inference. It is convenient to refer to the dynamic ether as *the* ether, because its reactions with matter apparently constitute most, if not all, of the phenomena usually attributed to an ether. Even light is quite probably a modification of it.

These views of the nature of ether, matter and energy coincide in general trend with the speculations of physicists over many years, recent years in particular. Both Boscovich and Faraday, for example, pointed out that the distinction between matter and non-matter is representable in terms of "force," and what is force but the intensity factor of energy? Tait tells us that "*Force is the rate at which an agent does work per unit of length,*"[21] a definition fitting the assumption of the radiation theory

[21]Tait, P. G., *Recent Advances in Physical Science*, p. 358.

regarding the cause of acceleration, the agent being radiation and the unit of length a unit of ether path. In short, *force is a manifestation of rate of energy exchange, and hence one particle of matter can exert no force on another if it can exchange no energy with it.* Maxwell also recognized that the only distinction between matter and non-matter is a distinction between the energy exchange effects observable in different parts of space. In fact, the terms "material" and "non-material" have been coined to express just this distinction. Thus he says:

"MATTER AND ENERGY.—All that we know about matter relates to the series of phenomena in which energy is transferred from one portion of matter to another, till in some part of the series our bodies are affected, and we become conscious of a sensation.

"By the mental process which is founded on such sensations we come to learn the condition of these sensations, and to trace them to objects which are not part of ourselves, but in every case the fact that we learn is the mutual action between bodies. This mutual action we have endeavored to describe in this treatise. Under various aspects it is called Force, Action and Reaction, and Stress, and the evidence of it is the change of the motion of the bodies between which it acts.

"The process by which stress produces change of motion is called Work, and, as we have already shown, work may be considered as the transference of Energy from one body or system to another.

"Hence, as we have said, we are acquainted with matter only as that which may have energy communicated to it from other matter, and which may, in its turn, communicate energy to other matter.

"Energy, on the other hand, we know only as that which in all natural phenomena is continually passing from one portion of matter to another."[22]

[22]Maxwell, J. C., *Matter and Motion,* chap. VI, pp. 163, 165.

The only difference between Maxwell's view of the relation between matter and energy and that of the radiation theory appears to be that the latter specifies the *kind* of energy which affords us our only acquaintance with matter. It is simply radiant energy. And this view is also suggested by the relativity theory and that of wave mechanics, both of which, in fact, are presumably partial expressions of the radiation theory. Even in the present stage of its development they are both, at least qualitatively, inferable from it with considerable probability.

Further confirmation of the view of the nature and relationship of matter and ether here maintained is contained in the conclusions of Comstock, derived from reasoning based on Maxwell's electromagnetic theory, entirely independent of the theory of relativity. He says:

"If second-order terms in the velocity [of a particle] be neglected, the mass is a simple constant multiplied by the total included electromagnetic energy. If the mass of ponderable bodies has an electromagnetic origin, then the inertia of matter is to be considered merely as a manifestation of confined energy. From this point of view, matter and energy are thus very closely related and the laws of the conservation of mass and energy become practically identical. . . . It has been shown that if material mass be electromagnetic and if lighter elements are formed from heavier ones through violent energy changes, it follows that gravity acts between quantities of confined energy and not between masses in any other sense."[23]

Thus the affirmative answer of the radiation theory to the question raised in this section is foreshadowed by the inferences of many physicists. If these inferences are correct, however, then not only energy, but mass, will have

[23]Comstock, D. F., "The Relation of Mass and Energy," *Phil. Mag.*, vol. 15, 1908, 6th Series, p. 20.

two kinds of "relativity" dependent upon motion. The old or classical kind has long been recognized by physicists, and is thus referred to by Preston:

"**All Motion and Energy Relative**:—In speaking of motion it must always be borne in mind that all estimation of it is necessarily relative, and for this reason no body considered by itself can be said to be either at rest or in motion. When we say a body is at rest, or moves uniformly in a right line, the estimation is made relatively to some system which we arbitrarily choose as fixed. Force, then, which is measured by the rate of change of motion (the word here meaning momentum, or mass multiplied by velocity) is also relative, and kinetic energy which is measured by half the product of the mass and the square of the velocity is also relative to the same system. Energy, then, in its estimation is relative, simply because velocity is relative.

"When we speak of the kinetic energy of a body or system, we always mean the energy with respect to some other chosen system, or else we mean nothing at all. This relativity of energy is sometimes lost sight of, and it is not uncommon to find the kinetic energy of a body spoken of as something quite independent of all modes of calculation."[24]

To this kind of relativity of energy (and hence of mass) the radiation theory adds a second, consequent on the radiational nature of matter and ether, namely, the relativity of the Doppler-displacements involved in the absorption and emission of radiation by matter. It is this second kind of relativity that is dimensionally expressed by the Einstein theory, and not any unique relativity of time and space, as assumed by the relativists.

Were mathematicians so inclined, there is no reason why they should not convert the kind of relativity re-

[24]Preston, Thomas, *The Theory of Heat*, pp. 81, 82.

ferred to by Preston into a relativity of time and space, since the magnitudes he mentions are different when measured from different co-ordinate systems, and just as much functions of the motion of such systems as the Einsteinian magnitudes. Hence just as much dependent upon the observer. If this fact has occurred to relativist authors, they seem not to have plainly stated it anywhere. At any rate, I have not discovered in their writings a clear recognition of the difference between these two kinds of relativity. Indeed, in later sections it will become plain that the relativists themselves are inclined to be deficient in their realization of the pervasive relativity of things, as humanly observable. Thus they recognize the relativity of energy due to Doppler-displacements, though they mistake the magnitude which is relative. But some of them at least belong to the class referred to by Preston, who have "lost sight of" the kind of relativity described by him, supposing it to be of a character "not dependent upon the observer," as Russell phrases it. Hence their distinction between "proper" and "relative" mass and energy, the first (objective) having physical significance and the second (subjective) not having it, involves a delusion. The distinction is between two kinds of mass and energy, to be sure, but both are relative and both have physical significance. The cause of this delusion is the blind, dimensional way of expressing the Doppler relativity. That this is the case will become apparent as we proceed, and especially in the section following.

Section 5. What is the cause of the increase of inertial mass with motion?

The experiments of Kaufmann and Bucherer early in the present century on the deflection of electrons in mag-

netic fields, have led physicists to infer that the inertial mass of bodies is not a constant, but increases with motion according to the formula:

$$(7) \quad M_v = M_o \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

where v is the velocity of the body, c the velocity of light, M_o the inertial mass when there is no motion, and M_v the mass at velocity v. This increase of mass is predicted by the relativity equations as a relativity phenomenon. That is, the increase is alleged to be relative to the observer and the mode of observation only. It is observable by a being observing by means of light when the velocity relative to him is v, but not observable by a similar observer moving with the electron. On account of the agreement of the relativity formula with the facts inferred from the Kaufmann-Bucherer experiment, Sommerfeld calls this experiment "the *experimentum crucis* of the theory of relativity."[25]

Now as equation (7) expresses a relativity departure of the mechanical behavior of bodies from classical laws, it must, according to the interpretation of the radiation theory, express a Doppler-displacement in radiation moving with the velocity c. And as the departure is due to the motion of the body relative to *something*, the inference that it is relative to the velocity of the radiation which the particle is emitting would seem to be a plausible one. Moreover, we need only glance at the denominator of the fraction on the right-hand side of the equation to realize that the expression is of a Doppler-like form appropriate to the expression of such an effect. If the theory of rela-

[25]Sommerfeld, A., *Atomic Structure and Spectral Lines*, p. 464.

tivity is the dimensional disguise that we have inferred it is, then the change of mass with motion should assume some such form as the one we find it assuming.

To show that the evidence supports this interpretation of the equation, let us turn to some further conclusions of modern physics. Russell, for instance, speaking of the newly formulated ideas about mass, tells us that:

"We have . . . two kinds of mass, neither of which quite fulfils the old ideal. The mass as measured by an observer who is in motion relative to the body in question is a relative quantity, and has no physical significance as a property of the body. The 'proper mass' is a genuine property of the body, not dependent upon the observer; but it, also, is not strictly constant. As we shall see shortly, the notion of mass becomes absorbed into the notion of energy."[26]

And in support of this contention, Einstein may be quoted as follows:

"A body moving with the velocity v, which absorbs* an amount of energy E_0 in the form of radiation without suffering an alteration in velocity in the process, has, as a consequence, its energy increased by an amount."

$$\frac{E_0}{\sqrt{1-\frac{v^2}{c^2}}}\text{''}$$[27]

*"E_0 is the energy taken up, as judged from a co-ordinate system moving with the body."

This statement can be expressed more explicitly in the language of relativity as follows: If on a body A moving relatively to a body B with velocity v, an amount of energy

[26]Russell, Bertrand, *The A B C of Relativity*, p. 150.
[27]Einstein, A., *Relativity*, p. 46.

E_0 in the form of radiation is absorbed without altering the velocity v, E_0 being the amount taken up as judged by an observer on A, observing by means of light, then a similar observer on B would judge the amount taken up to be $\frac{E_0}{\sqrt{1 - \frac{v^2}{c^2}}}$, or, if we express the increase of energy as judged by the observer on B by E_v, we have the equation:

$$(8) \qquad E_v = \frac{E_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Note the resemblance of this equation to (7) on page 96, and we have further confirmation of the hypothesis put forth in the last section, that matter, like light, is a form of radiation. For if it is not, how does it happen that the expression for its increase with motion is exactly the same as that which expresses the increase of radiation with motion? Can the identity of the two equations be a mere casual coincidence? If so, can we cite elsewhere in human experience a quantitative coincidence of this character which is merely casual? No, this identity of expressions is not an accident. It is due to the fact that matter is only a form of radiant energy, and therefore follows the same law of increase with motion as radiation in general. Any other conclusion would involve ignoring entirely the significance of coincidences. Quantitative coincidences, at any rate, are rarely casual.

But this at once raises the question emphasized by Russell that there are two kinds of mass, one with, the other without, physical significance. Can it be that we are confounding them? This may be the cause of some perplexity, especially when we recall that, according to the theory

of relativity, all increase of mass due to relative motion, is of the latter kind. The increase detected in the Kaufmann-Bucherer experiment is due to relative motion. Can it be explained by something which is without physical significance? That physical effects, like those detected in that experiment, can be explained by something or other which has no physical significance would seem to be a statement seriously lacking in intelligibility. Those who can make anything out of it may be congratulated for their insight. But perhaps there are not these two kinds of mass after all, and the notion that there are may be due to the verbal mix-up associated with all dimensional explanations.

To resolve this doubt in the present case let us inquire how radiation would be expected to increase with motion, if the relativity theory were left entirely out of account. We can see at a glance that it would be bound to increase in some manner, since the change in the Doppler-displacements of a moving radiating body is not a symmetrical one. Considering the increase of radiant energy alone it is plain that the wave-length of the radiation emitted in a direction opposite to that of the motion approaches twice its stationary value, as v approaches c, whereas that emitted in a direction coinciding therewith approaches zero. As the energy of radiation is inversely proportional to the square of its wave-length, it is evident therefore that the energy associated with a body emitting radiation approaches infinity as the velocity of the body relative to that of its own radiation approaches zero. This, of course, would be the velocity c relative to a body stationary with respect to the ether. The law of alteration of radiant energy, due to this cause, has been worked out by Larmor, and proves to be of great interest in connection with the

question raised in this section. Thus, referring to the increase of radiant energy by virtue of its motion (convection) through space, he says:

"By application of the Lorentz transformation in its exact form, . . . the effect of convection on the electrodynamic [radiant] energy . . . convected and unconvected . . . is expressed by

$$[8a] \quad E = \frac{E_o}{\sqrt{1 - \frac{v^2}{c^2}}}$$

where E_o is the energy in the unconvected state of the system."[28]

Larmor* in arriving at this result makes no reference to the theory of relativity, but applies the Lorentz transformation with the original interpretation of velocity relative to an ether. Thus the increase of energy shown, though due to motion, has plenty of physical significance. Given sensitive enough means of observation, a billiard ball, *A*, for example, would be found to impart on collision, a greater momentum to a second ball *B*, if *A* were warm than if it were cold, because of the greater radiant energy convected by the motion of the warm ball. In short, on Lorentz's theory, the effect of motion on radiant energy is to increase its amount in the degree specified in this equation. And according to Einstein, energy and matter are identical. Now Einstein continually maintains that the theory of Lorentz is right, only he disagrees with his "interpretation." Is it not clear, therefore, that

[28]Larmor, J., "Retardation by Radiation Pressure," *Collected Scientific Papers of J. H. Poynting,* p. 755.

*Dr. Snell's integration, showing the total increase of energy due to the Doppler-displacement agrees with Larmor's calculation (see p. 134.)

in this, as in other cases, Einstein's theory is merely a disguise for Lorentz's, the apparent disagreement about "interpretation" being a matter of words only? Comparing the two equations (8) and (8a), expressing change of energy with motion, can we seriously assert that the variation in the one case is due to something which "has no physical significance," as Russell expresses it, something "purely subjective . . . depending on our transformation of the reference frame of space and time" as Eddington phrases it (see quotation, page 104), whereas in the other case it is due to a straight convection effect, as Lorentz and Larmor maintain. Can concomitance so complete as to amount to coincidence be due to causes so totally different? To so assume is to do violence to reason.

This conclusion is confirmed by evidence furnished by the spectroscope. It is known that through the investigations of Sommerfeld, the Einstein equations receive confirmation from their application to the theory of spectral lines. According to the Bohr theory, the emission of such lines is caused by sudden changes in the orbits of electrons revolving about an atomic nucleus in orbits analogous to those in which the planets revolve about the sun. The assumed velocity of the electrons, however, is much greater than planetary velocities, and hence the increase of mass caused by their motion must, according to the relativity equations, be marked. And it is found that by applying the equations which allow for this increase to the orbital behavior of the electrons, the positions of spectral lines can be more accurately predicted than on the hypothesis of constancy of mass. But this confirmation of Einstein's theory, like that provided by the Kaufmann-Bucherer experiment, is no less a confirmation of the radiation theory, since the latter predicts the same increase

of energy and hence of mass with motion, the increase being expressed by the Larmor equation. This indeed is the non-dimensional explanation of the increase corresponding to Einstein's dimensional one.

It seems, therefore, safe to conclude that there is really no distinction between the two kinds of mass referred to by Russell at all. If one kind is identical with energy possessed of physical significance, the other is also, and thus the distinction disappears. The cause of the increase of inertial mass with motion then, is simply the increase of frequency due to Doppler-displacements in the radiation emitted by moving material bodies, and follows directly from the assumptions of the radiation theory.

Section 6. What is the cause of the Lorentz contraction?

It is well known that the negative result of the Michelson-Morley experiment stimulated mathematical physicists to contrive explanations thereof. In fact it was the stimulation afforded by this experiment that caused Einstein to evolve the theory of relativity. Apparently the first to propose an explanation, however, was Fitzgerald, who suggested that the motion of matter relative to the ether produced a shortening or contraction of the particles of which material bodies are composed in the direction of their motion just sufficient to cause the length of the two light paths involved in the experiment to become the same. In short, he suggested a second order compensating effect, supplementing the first order compensations, due to the familiar Doppler effect, which are known to occur in the experiment. This effect is extremely small at any velocities normally observable by physicists. The velocity of the earth in its orbit—something less than 19 miles a second—causes a contraction of only two and a half

inches in its diameter of 8,000 miles. Reasoning from electromagnetic principles which involved the assumption of an ether, Lorentz and Larmor showed that the compensation effect postulated by Fitzgerald was inferable from them. That the reasoning of these physicists is sound is not denied by the relativists. Thus Eddington remarks:

"This explanation [the contraction explanation] was proposed by Fitzgerald, and at first sight it seems a strange and arbitrary hypothesis. But it has been rendered very plausible by subsequent theoretical researches of Larmor and Lorentz. . . .

"The theory of Larmor and Lorentz enables us to trace in detail the readjustment [of the shape of the particle]. Taking the accepted formulæ of electromagnetic theory, they showed that the new form of equilibrium would be contracted in just such a way and by just such an amount as Fitzgerald's explanation requires."[29]

And Einstein endorses this position, as may be seen by noting what he says in the extract quoted on page 111.

In this connection we may again emphasize the inconsistency which characterizes the interpretations of physical phenomena by the relativists. Dimensionalism makes their explanations appear double. In the extract just quoted, for example, Eddington appears to agree with Lorentz and Larmor that the shape of the electron is distorted by its motion so as to become flattened in the manner described by them. But note what he has to say about the same electron in another place:

"The point is that every electron, at rest or in motion, is a perfectly constant structure; but we distort it by fitting it into the space-time frame appropriate to our own mo-

[29]Eddington, A. S., *Space Time and Gravitation*, pp. 19, 20.

tion with which the electron has no concern. The greater our motion with respect to the electron, the greater will be the distortion. The distortion is not produced by any physical agency at work in the electron; it is a purely subjective distortion depending on our transformation of the reference frame of space and time. This distortion involves a change in our physical description of the electron in terms of mass, shape, size; and in particular the change of mass agrees precisely with that found experimentally."[30]

And in yet another place he confirms this "subjective" interpretation of the contraction of material bodies in general:

"When a rod is started from rest into uniform motion, nothing whatever happens to the rod. We say that it contracts; but length is not a property of the rod; it is a *relation* between the rod and the observer."[31]

These extracts dispose us to change our minds about Eddington's agreement with Lorentz and Larmor, for these physicists say nothing of this subjective kind of contraction. They do not intimate that the contraction they refer to differs from the ordinary kind. Yet just as we are coming to the conclusion that there must be two kinds of contraction involved in this question, we turn to Eddington's discussion of the effect of the earth's motion on its shape, and without the slightest suggestion or implication that there are two kinds of contraction, or mass or anything else, he has this to say:

"There are other natural forces which have not as yet been recognised as coming within the electromagnetic

[30]Eddington, A. S., *The Theory of Relativity and Its Influence on Scientific Thought,* The Romanes Lecture, 1922, p. 21.

[31]Eddington, A. S., *Report on the Relativity Theory of Gravitation,* pp. 8, 9.

scheme—gravitation, for example—and for these other tests are required. Indeed we were scarcely justified in stating above that the diameter of the earth would contract 2½ inches, because the figure of the earth is determined mainly by gravitation, whereas the Michelson-Morley experiment relates to bodies held together by cohesion. There is fair evidence of a rather technical kind that the compensation exists also for phenomena in which gravitation is concerned; and we shall assume that the principle covers all the forces of nature."[32]

Thus a contraction which is "purely subjective" is caused by a variation in gravitation, cohesion or other *physical agencies.* "Nothing whatever happens," to the earth, any more than to the rod, but the nothing that happens is "determined" by recognized natural forces, and yet "is not produced by any physical agency." Is this reason, or anything remotely resembling it? Rather than so conclude, it would seem prudent to suspect that Eddington is having difficulty in discovering what he is talking about. Can his confusion be due to the same verbal hocus-pocus that led Russell to claim that there are two kinds of mass? That this is the explanation of the matter is made rather plain by noting his perplexity when he attacks the same problem in another place. Thus in the first chapter of his book, *The Nature of the Physical World,* a chapter entitled "The Downfall of Classical Physics," he says: "The Fitzgerald contraction may seem a little thing to bring the whole structure of classical physics tumbling down" (page 19), suggesting that it would be wise to at least understand it clearly before permitting it to accomplish the "tumbling down" process referred to. Now there is no reason to doubt that Eddington understands it as well as any relativist, but how well that is may be judged

[32]Eddington, A. S., *Space Time and Gravitation,* p. 21.

from what has gone before in this section, as well as from the extracts following. Thus on page 7 of the volume just quoted he tells us that: "The Fitzgerald contraction is not an imperfection [of a material body] but a fixed and characteristic property of matter, like inertia." And on page 8 he insists that "The Fitzgerald contraction is a necessary consequence of the scheme of electromagnetic laws universally accepted since the time of Maxwell." This all seems very explicit and free from doubt. But note what happens after the relativistic interpretation has introduced its verbalistic virus into the question. Turning to the next chapter, entitled "Relativity," we find the following question and distinction:

"Is it really true that a moving rod becomes shortened in the direction of its motion? It is not altogether easy to give a plain answer. I think we often draw a distinction between what is *true* and what is *really true*. A statement which does not profess to deal with anything except appearances may be *true;* a statement which is not only true but deals with the realities beneath the appearances is *really true*" (page 33).

And after a page of typical relativistic casuistry, the conclusion is reached that:

"The shortening of the moving rod is *true,* but it is not *really true*. It is not a statement about reality (the absolute) but it is a true statement about appearances in our frame of reference."*

*"The proper length . . . is unaltered; but the relative length is shortened. We have already seen that the word 'length' as currently used refers to relative length, and in confirming the statement that the moving rod changes its length we are, of course, assuming that the word is used with its current meaning" (page 34).

It is obvious from this, especially from the foot-note, that here is Russell's verbal distinction between "proper"

and "relative" *mass* applied to the Lorentz *contraction*. The ambiguity confuses Eddington as it did Russell, and, in the attempt to escape from the difficulty, he evolves a distinction between what is "true" and what is "really true," which is evidently a distinction between the "unreally" and the "really" true—a metaphysical distinction entirely unknown to science. We shall find, morever, in Section 23 that Einstein, when confronted with an even more difficult dilemma, evolves the same distinction between the "real" and the "unreal," thereby providing the reader with a bewildered impression that matters have somehow been explained, an impression that the evidence does not confirm.

This review of the relativistic account of the Lorentz contraction has been, perhaps, rather confusing; but it seemed worth while to present it as a sample of relativist ratiocination. It will be noted that it is exactly the kind of misunderstanding which is to be expected if a physicist is dealing with a Doppler-displacement, dependent as it is upon the motion of the observer, without recognizing the fact. The whole thing would appear to him "subjective" and unreal, but would become plain enough as soon as he recognized what his dimensional explanation was really disguising. Let us now turn to a line of reasoning which may throw somewhat more light on the matter.

The variation of the diameter of a material particle with velocity, according to Fitzgerald, Lorentz and Larmor, is:

$$(9)\quad D_v = D_o \sqrt{1 - \frac{v^2}{c^2}}$$

where v is the velocity of the particle relative to the ether, c the velocity of light in empty space, D_o the stationary

longitudinal diameter (*i. e.*, in the direction of motion) and D_v the diameter when moving with velocity v.

Compare this with the formula, given in Section 5, expressing the variation of the inertial mass of a material particle with velocity, as follows:

$$(10)\quad M_v = M_o \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

where v and c have the same meanings as in (9) M_o is the mass of the stationary particle and M_v that of the particle moving with velocity v.

If these formulæ are substantially correct—and they are generally accepted by physicists—it is clear that the variations of diameter and mass are concomitant. The two changes in fact are reciprocal functions of the velocity of the body. Velocity relative to what? According to the radiation theory, it is velocity relative to the ether and hence to its own radiation. But if these changes are due to Doppler-displacements—and strong reasons have already been given that the second one is—they will have the property of relativity, when observed by means of light signals, that all such displacements in radiation have. The laws of classical physics tell us this much. Neither the degree of motion nor proximity of neighboring bodies affect these variations. At least there is not the slightest reason to believe that they do. The relativists, to be sure, assume to the contrary, but, as noted on page 184, their alleged proof is invalid. The inference, therefore, seems irresistible that these two changes are causally connected with one another and with velocity relative to the ether. To infer otherwise is to brand as worthless one of Mill's canons of causation—that of *concomitant variations,* which tells us that, "What-

ever phenomenon varies in any manner whenever another phenomenon varies in some particular manner, is either a cause or an effect of that phenomenon, or is connected with it through some fact of causation."[33] When the concomitance is quantitative, as in the case we are considering, the evidence of causal connection is particularly strong. Hence to deny its application in this case is to eliminate a rule of inductive inference upon which countless other conclusions in science and every-day life depend.

Now the two experiments on which these concomitant formulæ are based are cited by relativists as peculiarly crucial confirmations of the theory of relativity. That of Michelson and Morley in fact is the original foundation stone of the theory, and that of Kaufmann and Bucherer, as noted on page 96 is called by Sommerfeld the "*experimentum crucis*" of the theory. These formulæ, therefore, are of critical importance in deciding whether the claims of the relativists are maintainable that they constitute crucial verifications of the relativity, and hence refutations of non-relativity, assumptions. According to the reasoning indicated in Chapter II, they constitute no such thing. For if the experiments are crucial in establishing the relativity theory, they are equally crucial in establishing the non-relativity theory, there being no more difference between the two than between any other pair of concurring dimensional and non-dimensional explanations. In fact we find in this agreement between the predictions of Lorentz and Einstein the same concurrence between the two theories that we found when considering the Fizeau experiment in Chapter III, showing again that the apparent disagreement between them is no more than a matter of words, resulting from the shift of meanings

[33]Mill, J. S., *System of Logic,* book 3, chap. 8.

pointed out in Chapter I. That this hypothesis is correct is confirmed by Einstein himself in the following words:

"To what extent is the special theory of relativity supported by experience? This question is not easily answered for the reason already mentioned in connection with the fundamental experiment of Fizeau. The special theory of relativity has crystallised out from the Maxwell-Lorentz theory of electromagnetic phenomena. Thus all facts of experience which support the electromagnetic theory also support the theory of relativity. As being of particular importance, I mention here the fact that the theory of relativity enables us to predict the effects produced on the light reaching us from the fixed stars. These results are obtained in an exceedingly simple manner, and the effects indicated, which are due to the relative motion of the earth with reference to those fixed stars, are found to be in accord with experience. We refer to the yearly movement of the apparent position of the fixed stars resulting from the motion of the earth round the sun (aberration), and to the influence of the radial components of the relative motions of the fixed stars with respect to the earth on the colour of the light reaching us from them. The latter effect manifests itself in a slight displacement of the spectral lines of the light transmitted to us from a fixed star, as compared with the position of the same spectral lines when they are produced by a terrestrial source of light (Doppler principle). The experimental arguments in favour of the Maxwell-Lorentz theory, which are at the same time arguments in favour of the theory of relativity, are too numerous to be set forth here. In reality they limit the theoretical possibilities to such an extent, that no other theory than that of Maxwell and Lorentz has been able to hold its own when tested by experience."[34]

Einstein then goes on to show that the Michelson-Morley experiment at first presented a difficulty to the Max-

[34]Einstein, A., *Relativity*, pp. 49, 50.

well-Lorentz theory (since a second-order, as well as a first-order, Doppler-displacement effect had not been anticipated by physicists), but, as he proceeds to point out:

> "Lorentz and Fitzgerald rescued the theory from this difficulty by assuming that the motion of the body relative to the ether produces a contraction of the body in the direction of motion, the amount of contraction being just sufficient to compensate for the difference in time mentioned above. Comparison with the discussion in Section XII shows that also from the standpoint of the theory of relativity this solution of the difficulty was the right one."[35]

Thus the agreement of the two theories is again asserted by Einstein. (Compare quotation from him on page 42, Chapter III.) But immediately following this acknowledgment, he expresses dissatisfaction with Lorentz's "interpretation" of the experiment, because that physicist postulates an ether. To this expression of dissatisfaction we shall return in Chapter VII, wherein the relativity "interpretations" are questioned, and shall undertake to show that by departing from Lorentz's ethereal interpretation, Einstein not only gets into hopeless difficulties with the most familiar facts, but is forced to contradict himself. The radiation theory agrees with Lorentz that motion of particles relative to the ether is the cause of the variations discoverable by experiment and expressed in formulæ (9) and (10), but it specifies something about the ether that Lorentz neither affirms nor denies, namely, that it is a radiant ether, of which the particle is a modification.

Owing to lack of mathematical development, however, the position of the radiation theory with respect to the Lorentz contraction is at present in some doubt. That it is

[35] *Ibid.*, p. 53.

due to a radiation displacement admits of little question, since the contraction of a material body, if said body is composed of radiation, must involve a radiation displacement. Moreover, it is obviously a displacement involving the second power of v, as Lorentz maintains, but the mechanism is obscure, an obscurity reflected in the words of Eddington quoted on page 105. The main question seems to be: Is it an effect due to an interaction between recognizable material particles—atoms, electrons and molecules—or is it a contraction of the materion itself? According to Lorentz, it would seem to be of the former character, as indicated in the following passage:

> "This dependence of the dimensions [of bodies on the earth] upon the orientation with respect to the earth's motion is not as strange as it might seem at first. In fact, the dimensions are determined by molecular forces, and since these are transmitted through the ether, it would rather be surprising if its state of motion had no influence upon the dimensions of bodies. The nature of the molecular forces is not known to us. Yet, if we suppose that they are transmitted through the ether in the same way as electric forces [and hence with velocity c], we can develop the theory of this contraction, and we then find for its amount just what is required for the explanation of the nil-effect of Michelson's experiment."[36]

Without expressing any dissent from this statement—for the predictions of the radiation theory in this connection are unknown—we may suggest another possible interpretation of this alleged "contraction," which certainly follows from the radiation theory. That is to say, the latter theory requires a "condensation" of materions in the direction of their motion, resembling very considerably the

[36]Lorentz, H. A., *Lectures on Theoretical Physics*, vol. 1, p. 23.

Lorentz contraction, but just what the effect would be on bodies having the dimensions of the earth or an interferometer arm, subject to forces of gravitation, cohesion, etc., is at present conjectural. The concomitance expressed in the equations on pages 107 and 108, however, indicates that this longitudinal condensation of the materion may be a true interpretation of the Lorentz contraction. The condensation, of course, is a Doppler-displacement. That is, the materion, being composed of radiation and emitting it, is subject to Doppler-displacements in the direction of its motion to which it is not subject in directions at right angles thereto. As the condensation of the waves in front increases faster with motion than the rarefaction behind, the total result is that the radiation which constitutes the moving materion becomes more concentrated or condensed the faster it moves, the limit approached as the materion approaches the velocity of its own radiation being an infinite condensation in the direction of motion, but an unchanged condensation in directions at right angles thereto. It is obvious that this corresponds to the "contraction" of the substance (energy) of the material particle to zero diameter in the direction of motion with unchanged diameter in directions at right angles thereto required by Lorentz's theory, as the velocity of the particle approaches that of light.

This discussion of the Lorentz contraction leaves its cause in doubt. Indeed, an actual longitudinal "contraction" of molar aggregates, such as the earth, is not at present predictable from the radiation theory, and this perhaps is another weak feature of it. But at least an increased longitudinal "condensation" of isolated particles, concomitant with the increase of mass with motion, and due to a common cause, is predictable. Moreover, this

phenomenon, being a Doppler-displacement, would have the character of relativity required by the relativity theory of the Lorentz contraction, thus again confirming the view expressed in Section 2, that the relativity equations are everywhere disguises for Doppler-displacements.

Section 7. What is potential energy?

Physicists divide energy into two kinds, kinetic and potential, the former being the energy which a body possesses by virtue of its motion, the latter that which it possesses by virtue of its position relative to other bodies. Now we know that when the kinetic energy of a body is changed, there is a change of rate of motion, and that the change in energy bears a definite relation to the amount of this change. But physicists have been unable to express change of potential energy in this way. The change of kinetic into potential energy, however, and *vice versa* is a very direct change. It occurs at every swing of a pendulum for instance, and in the process of tossing a ball from one person to another. It is characteristic of energy that when it disappears in one form it reappears in another. Position and motion, however, are so unlike in nature that it seems a little puzzling to regard them as two forms of the same thing. Can position be motion in a different form? Many of the early physicists, in fact, were disposed to the view that all forms of energy depend in some way on motion, and that in the last analysis the law of the conservation of energy would be found to be a law of conservation of motion. No proof of this view, however, has been forthcoming, but that potential energy is an anomalous form of energy, calling for explanation, is a view which nevertheless has persisted. Faraday, for instance, whose intuitions were usually sound, was unable to

rest satisfied with the statement that when energy in some palpable form, such as heat, disappears, it has simply become "potential" or "latent." Recalling that in Faraday's time, energy was called force, the following expressions of his are of interest. Speaking of the law of conservation he remarks:

"We ought, in every hypothesis, either to account for its consequences by saying what the changes are when force of a given kind apparently disappears, as when ice thaws, or else should leave space for the idea of the conversion. . . . The deficiency should never be accepted as satisfactory, but be remembered and used as a stimulant to further inquiry; for conversions of force may here be hoped for. . . . The case of a force simply removed or suspended, without a transferred exertion in some other direction, appears to me to be absolutely impossible."[37]

Clerk Maxwell's words are also of interest in this connection. He says:

"In a watch, the mainspring, when wound up, has potential energy, which it spends in driving the wheels of the watch. This energy arises from the coiling up of the spring, which alters the relative position of its parts. In both cases, until the clock or watch is set agoing, the existence of potential energy, whether in the clock-weight or in the watch-spring, is not accompanied with any visible motion. We must therefore admit that potential energy can exist in a body or system all whose parts are at rest.

"It is to be observed, however, that the progress of science is continually opening up new views of the forms and relations of different kinds of potential energy, and that men of science, so far from feeling that their knowledge of potential energy is perfect in kind, and incapable of essential change, are always endeavouring to explain

[37]Faraday, Michael, "The Conservation of Force," *The Correlation and Conservation of Forces,* p. 362.

the different forms of potential energy; and if these explanations are in any case condemned, it is because they fail to give a sufficient reason for the fact, and not because the fact requires no explanation."[38]

The implication here that potential energy, in its apparent independence of motion, is a fact calling for explanation, is quite plain. Tait states the case even more emphatically. Under the heading "Potential energy kinetic," he has this to say on the subject:

"When two measurable quantities, of any kind, are equivalent to one another, their numerical expressions must involve the same fundamental units, and in the same manner. This is obvious from the fact that an alteration of any unit alters in the inverse ratio the numerical measure of any quantity which is a mere multiple of it. And equivalent quantities must always be expressed by equal numbers when both are measured in terms of the same system of units. It appears, therefore, from the conservation of energy directly, as well as from the special data in §§ 111, 113, that potential energy must, like kinetic energy, be of dimensions $(ML^2\,T^{-2})$.

"Now it is impossible to conceive of a truly dormant form of energy whose magnitude should depend in any way on the unit of time; and we are therefore forced to the conclusion that potential energy, like kinetic energy, depends (in some as yet unexplained, or rather unimagined, way) upon motion. For the immediate purposes of this article the question is not one of importance. We have been dealing with the more direct consequences of a very compact set of laws, exceedingly simple in themselves, originally based upon observation and experiment, and, most certainly, true. But reason cannot content itself with the mere consequences of a series of observed facts, however elegantly and concisely these may be stated by the help of new terms and their definitions. We are forced to in-

[38]Maxwell, J. C., *Theory of Heat,* p. 309.

quire into what may underlie these definitions, and the laws which are observed to regulate the things signified by them. And the conclusion which appears inevitable is that, whatever matter may be, the other reality in the physical universe, energy, which is never found unassociated with matter, depends in all its widely varied forms upon motion of matter. In some cases we are sure, in others we can as yet only suspect, that it depends upon motions in a medium which, unlike ordinary matter, has not yet been subjected to the scrutiny of the chemist. But the question, in its generality, is one of the most obscure in the whole range of physics. In the articles ATOM, ATTRACTION, ETHER, will be found nearly all that is yet known on this profoundly difficult subject. But to what is there said must be added the remark that a state of strain of the ether, whether associated with the propagation of light and radiant heat or with a statical distribution of electricity, represents so much 'potential' energy, and must in its turn in some way depend on motion."[39]

It is perhaps superfluous to point out the foreshadowing of the radiation theory contained in this passage. The insistence that ether "strain" is a dynamic and not a static phenomenon, is particularly significant. Indeed, if Tait's reasoning is correct, some sort of radiation theory is a necessity of classical (Newtonian) mechanics. This fact takes on added significance when we note what is made plain on page 119, namely, that the mechanics of relativity also require a radiation theory of some kind in order consistently to maintain the position best expressed perhaps by Lewis and Tolman. *Moreover, both kinds of mechanics require a radiation theory at exactly the same point, viz., where material bodies change their velocity.*

That Preston shares the views of Tait, and foreshadows

[39]Tait, P. G., article "Mechanics," *Encyclopædia Britannica*, 9th Edition, vol. 15, p. 748.

the radiation theory still more explicitly, is clear from the following statement of his position:

"The question still remains, what becomes of the motion when the kinetic energy of a system diminishes? Can motion ever be changed into anything else than motion? If we assume a fundamental medium whereby to explain all the phenomena of nature, then the properties of this medium ought to remain unchanged, and all other changes must be explained by motion of the medium. Such an assumption is quite philosophic, and the method of procedure is certainly scientific. An evident reply to the question of what becomes of the motion of a projectile rising upwards is that it passes into the ether. The first assumed property of the ether is that it can contain and convey energy. There is no *apriori* reason, then, why the energy of motion of a projectile as it rises upwards should not be stored up as energy of motion of the ether between the body and the earth, or elsewhere. The oscillation from kinetic to potential, and from potential to kinetic, in the case of the pendulum is then, from this point of view, merely an interchange of energy of motion going on between the mass of the pendulum and the ether around it. According to this view all energy is energy of motion, and must be measured by the ordinary mechanical standard. The work we do in lifting a body from the earth is spent in generating motion in the ether, and as the body falls this motion passes from the ether to the body, which thus acquires velocity. In the same way, the work spent in generating electric currents and electrifying conductors must be represented as spent in generating motion of the ether around the electric circuits and conductors. . . . If motion passes from one body it must either pass into other bodies or else into the ether, so that all energy is kinetic, and what we call potential energy, or energy of position of a system, is energy of motion in the ether, which has left the system and become located in the ether, and which may be regained by the system from the ether. The oscillation of energy, then, is from ether to matter, and from

matter to ether, and on this oscillation all the physical life of the universe depends."[40]

Another significant adumbration of the radiation theory is to be found in a recent essay of Thomson, as follows:

"It is generally recognised that the transmission of electrical energy is by waves through the ether: can we go further and say that energy of all kinds is transmitted in this way? It may quite well be that this is not really going further, for all energy may be of the same kind, located in the ether and having to travel through it."[41]

The implication of this passage* is very plain, but no plainer than that of the following, taken from an article by two American relativists:

"When a body is in motion its energy and mass are both increased, and the increase in energy is equal to the increase in mass multiplied by the square of the velocity of light. From the conservation laws we know that when a body is set in motion and thus acquires mass and energy, these must come from the environment. So also when a moving body is brought to rest it must give up mass as well as energy to the environment."[42]

The exchange of energy with the "environment" here mentioned is an exchange with the ether—the common

[40]Preston, Thomas, *The Theory of Heat*, p. 90.

[41]Thomson, J. J., *Beyond the Electron*, 1928, p. 13.

*Another adumbration of the radiation theory by Sir Oliver Lodge, too long to quote, may be found in *Nature*, vol. 106, p. 799. While Lodge does not clearly grasp the dimensional character of Einstein's theory, he does recognize that it is a mathematical disguise of some sort, and that the thing it is disguising is in the nature of an energy-filled space, or some vital feature thereof. For, after sketching a somewhat vague picture of such a space, he says: "This is what the Einstein theory, in its own peculiar geometrical unphysical way has grasped."

[42]Lewis, G. N., and Tolman, R. C., "The Principle of Relativity and Non-Newtonian Mechanics," *Phil. Mag.*, 6th series, vol. 18, p. 521.

environment of all material bodies, irrespective of size, and their *only* immediate environment. The planets, for example, moving in elliptic orbits, are constantly changing their velocities. Hence, according to Lewis and Tolman, they must be constantly exchanging energy with their environment. But their only environment is the ether, and how can they exchange energy with it, if it is static and hence incapable of either giving up or receiving energy? How can "mass and energy . . . come from the environment" if said environment is mere emptiness from which nothing can come? Moreover, if energy is thus exchanged with the environment, when a body changes its rate of motion, what kind of energy can come from, and be given up to, the only common environment of bodies, except radiant energy? It should also be noted that the energy thus passed back and forth is mass as well as energy. Hence potential energy is also potential mass. And what form could potential mass take in the environment of an accelerating planet or comet except that of radiation? Can mere position be a form of mass as well as energy? The concepts of mass, energy and ether suggested by the radiation theory render such statements as we have been quoting both intelligible and plausible, but on the assumption of a static ether or an empty space, they express nothing but nonsense.

Another investigator agreeing with Maxwell and Tait about the nature of potential energy, has also arrived at results foreshadowing the radiation theory. This is MacDonald, who begins his chapter entitled "Dynamical Theory," as follows:

"The tendency of physical investigations has in general been towards the construction of a dynamical theory which shall give a consistent account of phenomena, the path pur-

sued being to arrive at such a result by inductive methods. The fundamental idea underlying attempts at a theory of this kind is that direct knowledge is confined to a knowledge of motions, the other ideas of dynamics, such as force, being inferences which are useful aids in classifying and explaining phenomena in terms of those phenomena which are more intimately known."[43]

Proceeding then to build up a deductive dynamic theory, using the Lagrangian function as an expression of motions only, he derives formulæ from which he draws the following conclusion:

"On this view then potential energy is the energy of what may be termed the concealed motions, that is the energy of those motions which correspond to degrees of freedom which are not directly observed."[44]

And again:

"It appears . . . that on a dynamical theory the existence of a potential energy function necessitates the existence of concealed motions."[45]

That changes of potential energy are as much changes of motion as changes of kinetic energy are, follows as a consequence of the radiation theory. A cannon-ball fired vertically upward from the earth's surface, for instance, gradually loses kinetic, and gains potential, energy, due to the unbalanced radiation pressure which constitutes the earth's gravitational field, the kinetic energy being transferred to the ether in the form of increased ethereal radiation. Having been brought to rest relative to the earth by this process, its path is immediately reversed, the same

[43]MacDonald, H. M., *Electric Waves*, p. 35.
[44]*Ibid.*, p. 38. [45]*Ibid.*, p. 46.

agency which produced retardation now producing acceleration, and when it reaches its starting point at the earth's surface (ignoring frictional effects due to the atmosphere) it has lost its potential, and regained its original kinetic, energy, having absorbed it from the excess radiation of the earth's gravitational field, the ethereal reservoir of energy having been diminished thereby through decreased ethereal radiation.

If we consider a light-absorbing particle of mass m changing its rate of motion in a beam of light, the energy transmutations will be strictly analogous. When moving against the beam, and hence retarded by it, so as to decrease from a velocity v_1 to a velocity v_2, it will lose kinetic energy of amount $\frac{1}{2} m v_1^2 - \frac{1}{2} m v_2^2$ and hence, according to the first law of energy, must re-radiate, during the interval of retardation, just that much more light than it would have done had the beam produced no change of motion in it. This is one-fourth the amount of energy which would have been added to the ethereal reservoir had the mechanism of retardation been reflection instead of absorption, since reflection changes the wave-length twice as much as absorption and hence the energy four times as much. At least such a conclusion follows if it is assumed that the change of energy is representable in terms of wave-length, the amplitude remaining unchanged. Similarly, when by this process the particle has been constrained to move in the same direction as the beam, a gain in kinetic energy from $\frac{1}{2} m v_2^2$ to $\frac{1}{2} m v_1^2$ will be accompanied with a diminished radiation of the same amount of energy during the period of acceleration. To obtain the complete effect, of course, we must allow for the fact that the energy of the emitted radiation itself, is a function of its velocity rela-

tive to the emitting body. That is to say, we must change

$\frac{1}{2}mv_1^2$ to $\dfrac{\frac{1}{2}mv_1^2}{\sqrt{1-\frac{v_1^2}{c^2}}}$ and $\frac{1}{2}mv_2^2$ to $\dfrac{\frac{1}{2}mv_2^2}{\sqrt{1-\frac{v_2^2}{c^2}}}$. This is what

the relativists call a "relativity" correction,* but the laws of classical physics call for it just as much as the equations of relativity, when once we realize what is really happening. The relativists attribute this correction to a relativity of time and space because of their misinterpretation of the Doppler-displacement.

If this is the correct account of affairs, then it is clear that Maxwell, Tait and Preston were not mistaken in surmising that so-called "potential" energy is no more potential than kinetic energy is. Kinetic energy is a potentiality of ethereal energy in the same sense that potential energy is a potentiality of kinetic. Both are forms of motion. Human powers of observation happen to be so limited that the material motion is observable, whereas the ethereal is not, a circumstance of more interest to man than to nature. According to the radiation theory, however, the ethereal kind though concealed is no more "unimaginable" than the other. It is the same kind of motion familiar to us as light, only of different wave-length. Potential energy then is energy transferred to the ether by the movement of matter against unbalanced radiation pressure.

That so-called potential energy will be expressible in terms of the position of one body relative to another follows from the radiation theory if we accept the conclusion arrived at in Section 9 that Doppler-displacements alone cannot unbalance radiation and hence cannot pro-

*The correction given is slightly simplified mathematically.

duce change of motion. For if this is the case, then change of motion can occur only when there is lack of balance due to an excess or deficit of pressure-producing power in radiation emanating from some source or sources thereof other than Doppler-displacements alone. The only such sources at present recognized by the radiation theory are material bodies, and hence the only way in which change of *amount* of motion in a body can be produced is by a change of position of one body relative to another, or several others. Moreover, this change in amount must be expressible in an approach or recession, since a change involving neither—a change at right angles to the direction from which the lack of balance is proceeding—can be only a change in *direction,* and hence cannot change the frequency either of the in-falling or emitted radiation. Hence it can alter neither the potential nor the kinetic energy. This prediction agrees with the facts as we find them, and shows why potential energy is representable in terms of the position of a body relative to other bodies, and why it can be changed only by a change of position confined to a recession or approach. Which of these changes in position will result in increase of potential energy will depend upon whether the lack of balance is a deficit of pressure-producing power proceeding from the neighboring body, resulting in attraction, or an excess, resulting in repulsion. The latter, of course, is not to be found in gravitational fields, though common enough in electric and magnetic ones.

One other treatment of this question, by Tolman, may be noted here, since it comes about as near clinching the argument for the radiation theory as circumstantial evidence of this general character can come. Thus in a discussion of "The Relation between Mass and Energy" in

the third chapter of his book on relativity, Tolman has this to say:

"The theory of relativity has led to very important conclusions as to the nature of mass and energy. In fact, we shall see that matter and energy are apparently different names for the same fundamental entity."[46]

According to the radiation theory this "same fundamental entity" is radiation. He then goes on to give the mathematical argument for the identification of mass and energy, an argument fitting Lorentz's non-relativity assumptions as well as the relativity ones; and at the close thereof, referring to the moving particle to which his argument applies, he says:

"If now we bring the particle to rest it will give up both its kinetic energy and its excess mass. Accepting the principles of the conservation of mass and energy, we know, however, that neither this energy nor the mass has been destroyed; they have merely been passed on to other bodies. There is, moreover, every reason to believe that this mass and energy, which were associated together when the body was in motion and left the body when it was brought to rest, still remain always associated together. For example, if the body should be brought to rest by setting another body into motion, it is of course a necessary consequence of our consideration that the kinetic energy and the excess mass both pass on together to the new body which is set in motion. A similar conclusion would be true if the body is brought to rest by frictional forces, since the heat produced by the friction means an increase in the kinetic energies of ultimate particles."[47]

All this coincides with the conclusions of the radiation theory. But another case, which he does not mention, is of even greater interest than that of the transfer of energy

[46]Tolman, R. C., *The Theory of the Relativity of Motion*, p. 39.
[47]*Ibid.*, p. 40.

by collision or friction, which he does mention. It is a case where the transfer to other material bodies in the manner described is impossible. Thus we may inquire: What becomes of this entity when the particle or body is brought to rest in empty space by the force of gravitation, as in the cannon-ball example, for instance? Obviously there is no place for it to go except the ether, and if it goes there it must be in the form of radiation, since no other form of energy is found there. As no one claims it is in the form of light or radiant heat, it must be in some form not recognized by those who postulate a static ether. If we assign the name X to the energy into which the kinetic energy of a body is transformed during retardation in empty space, then four alternatives present themselves: (1) Neither matter nor X consists of radiation. (2) Matter consists of radiation, but X does not. (3) X consists of radiation, but matter does not. (4) Both matter and X consist of radiation. The fourth alternative is that postulated by the radiation theory. And in view of the form of energy to which empty space is presumably limited, it is the only one compatible with Tolman's conclusion that matter and energy constitute "the same fundamental entity," and that "the mass and energy, which were associated together when the body was in motion and left the body when it was brought to rest, still remain always associated together." If matter and energy both consist of the fundamental entity radiation, then on the fourth alternative, they can stay together in the body and remain together on leaving it when the body is brought to rest, or retarded, by gravitation at a point in space remote from anything but "empty" space. But on any of the other alternatives they cannot remain together as any form of energy known to science.

Another point worth noting in this connection is that the identity of mass and energy called for, both by the assumptions of relativity and those of the radiation theory, imply that the ether is the principal seat of all energy interchanges accompanying changes of motion of material bodies. Indeed, as noted on page 119, this implication is explicitly expressed, at least as a surmise, by Thomson. For if the radiation theory is sound, the change from kinetic energy and mass to potential, and *vice versa,* is due to a change of frequency of radiation emitted by matter, and this change is presumably transmitted to the ether with the speed of light. Hence it is not confined to the emitting particle, but spreads through the universe. In the case of positive acceleration relative to the ether, the increase of energy moves in the direction of increased motion, and hence increased momentum, of the particle, and in the case of negative acceleration, in the opposite direction. But increased momentum cannot be imparted to a body without a compensating decrease, direct or indirect, in the body or bodies from which it receives said increase, because, according to Newton's third law, action and reaction are equal. This third law, indeed, appears to be a consequence of one yet more fundamental, namely, that any local increase of the momentum in a given direction of the radiation comprising the energy-containing universe, whether in the form of material momentum or otherwise, is always balanced by an increase in the opposite direction. Furthermore, if we trace these divergent momenta to the forces which produce them, we shall find that there is a compensating change of momenta associated therewith. If, for example, two material bodies are urged in opposite directions by the expansion of a gas, the increase in momentum of the bodies

will be compensated by a decrease in momentum of the particles of which the gas is composed, and it will consequently fall in temperature. In short, the radiational momentum of the universe as a whole—and all its momentum is radiational—is unchangeable. This law may, with considerable plausibility, be regarded as a very comprehensive one, of which not only Newton's laws of motion are consequences, but also the laws of conservation of energy, momentum and mass. It is not, however, advanced as a law which is fully confirmed, but simply as a speculation suggested by the radiation theory and the facts on which it rests.

The radiation theory causes the facts of potential energy to dove-tail very closely with the conclusions of many able physicists drawn from various fields of observation and inference, including those of gravitation and inertia and their curious change with motion. This intricate dovetailing may be only a set of coincidences, but the probability against such a conclusion is very great. Thus by identifying the ether with ethereal radiation, and matter with a modification of the ether, the radiation theory reconciles the relativity theory—or at least its equations—with the classical theory, and dispels the mystery of change of mass with motion and the connection of potential energy with motion at the same time, and does it without recourse to any metaphysics or *ad hoc* hypotheses.

Section 8. What is the cause of inertia?

Inertia manifests itself whenever a material body changes its amount or direction of motion. It is in fact a kind of resistance to change of motion, and is a direct function of the time required to accomplish a given amount of change under the influence of a given force.

Now when a body is accelerated relatively to the ether, positively or negatively, a transformation of energy occurs, and if the radiation theory is sound, positive acceleration involves a transmutation of ethereal into kinetic energy, and negative acceleration (retardation) a transmutation of kinetic into ethereal. This requires time, and as the transmutation involves all materions, the amount of time (the force remaining the same) will be proportional to the number of materions (amount of matter) in the body. Thus, according to the radiation theory, inertia is merely a manifestation of the fact, observable in all realms of nature, that the transformation of energy from one form to another requires finite time intervals.

To change, in any finite degree, the rate of motion of a body, in no time at all, would, if our assumptions are sound, require an infinite rate of energy interchange. It is evidently because nature possesses no mechanism for bringing about such rates of interchange that the movements of bodies can suffer change only in finite time and therefore in finite length. We may also surmise that nature possesses no mechanism for bringing about instantaneous changes in the direction of a body's motion, and that this is why such changes do not occur. These conclusions, indeed, are perhaps superfluously obvious. Just why mechanisms for infinite rates of change of motion are not possessed by nature is not known, but the reason is doubtless connected with the (at least hypothetical) fact that radiation itself, through which all change of motion is brought about, possesses only finite velocity.

If we assume mere position relative to other bodies to be a form of energy, the conclusion that inertia is a time and length lag effect of energy interchange would follow, even in the absence of the radiation theory. But here

again, the classification of motion and position together as forms of the same magnitude is so incongruous that the association of potential energy and mass with motion, required by the radiation theory, may be counted as a factor in its favor. If therefore the radiation theory offers no completely new explanation of inertia, it at least renders the old one more specific and less incongruous. Moreover, the specific character of the energy interchange postulated by that theory enables it to make certain predictions, amply confirmed by the facts, which the old explanation is unable to make. Among these may be included that of the law of increase of inertial mass with motion.

In Section 23 it will be shown that the facts of inertia are among the most critical in invalidating the assumptions (though not the equations) of relativity and confirming those of the radiation theory. The present brief explanation, therefore, will at this point be sufficient.

It will be pertinent, nevertheless, to note here how the evidence for the cause of inertia, cited especially in Sections 4 and 5, re-enforces that cited in Section 1, for the cause of gravitation. These lines of evidence are quite independent of each other and hence are mutually confirmatory. This mutual confirmation is impressively emphasized by Galileo's discovery of the proportionality of inertia and gravitation, a fact hardly compatible with the supposition that their causes are independent. Furthermore, as Einstein has pointed out (see Section 21), an inertial field, under certain circumstances, can simulate a gravitational one so closely that the familiar laws of falling bodies obtain therein, even in the absence of gravitation. This fact so impresses the relativists that they assert inertia and gravitation to be identical. Without taking a position so extreme as this, we are nevertheless

justified in concluding that such a similarity, combined with a concomitance amounting to actual proportionality, of the character noted by Galileo, is powerful evidence of an identity in their causes. Moreover, the independent, yet converging, evidence cited in Section 1 and Sections 3 and 4 respectively, that their causes are radiational in nature, provides a mutually supporting structure of undoubted stability, especially when we consider the additional interlocking evidence for the radiation theory disclosed in later sections.

Section 9. Why are not material bodies retarded in their motion through space?

That the heavenly bodies are subject to no retardation in their motion through space appears, on the old theories of matter, to be a fact difficult to reconcile with the existence of an ethereal medium which behaves like an elastic solid. But if we accept the theory that matter consists of nodes or standing waves, or some other modification of radiation, it will become at once evident that there is no reason why it should be retarded in space by the process, whatever it is, whereby one solid body obstructs the movement of another in contact with it. Thus the theory to which the whole wave mechanics movement is trending changes our view of the nature of impenetrability and reconciles the unimpeded motion of the heavenly bodies through space with the elastic solid theory of the ethereal medium. In short, if matter is composed of radiation in such a medium, there is no more reason *apriori* why it should be impeded than light or any other kind of radiation existing therein. As the radiation theory is in harmony with this trend, the old objection to the elastic solid theory does not apply to it. Impenetrability appears to be

a reaction between radiation and radiation, of an unknown nature to be sure, but at any rate not a reaction between matter and the medium of whose motion matter itself consists. Indeed, as noted in Section 4, the radiation theory reduces all reactions between space-occupying agencies known to physics to reactions between radiation and radiation. The most familiar examples of such reactions are provided by the phenomena of interference and reflection. The mechanism of these reactions is obscure, but the theory thereof offers no greater difficulties at least, than theories of the mechanism whereby radiation would react with non-radiation. Physics is ignorant of the details of either mechanism, and is likely for some time to remain so.

But to take the place of the old objection to a solid-like medium, which the radiational theory of matter removes, another one would at first sight appear to arise. For if matter behaves like a radiating body, why are not the Doppler-displacements arising from its motion themselves sources of retardation? Both the in-falling and emitted radiation would appear to be such sources since in the case of both, the energy density in front of a moving body will be greater than that behind it, and thus a difference of pressure will be set up tending to retard the body. The non-retardation of the heavenly bodies then, would appear to offer a refutation of the radiation theory.

In view of the evidence from other sources favorable to the theory, however, we may suspect that some compensating influence is set in operation by a freely radiating body in a uniform field of radiation, which nullifies this effect. The fact that X-rays increase in penetrating power as they increase in frequency, and that the greater the penetrating power the less the pressure, suggests that per-

haps a compensating effect of this character is responsible for the non-retardation of moving bodies in space. At my request, Dr. George D. Snell has investigated the possibilities of this assumption, and arrived at some interesting results. The most important of these he has briefly epitomized as follows:

"If a particle is stationary relative to a field of highly penetrating radiation moving equally in all directions it is subject to balanced pressures on all sides. Opposite faces receive the same number of waves per second and hence are subject to the same forces.

"If, however, the particle is moving relative to the ether a different situation prevails. Due to the well known Doppler principle an excess of radiation is encountered on the forward face as compared with the rear, and this excess, in the absence of some compensating effect, will tend to retard the motion. The waves reaching it per second from in front outnumber those reaching it from behind, and if equally effective in producing pressure, will bring it to rest. This tendency is further accentuated by the reradiated radiation, for that given off from the forward face causes more back-pressure than that given off from the rear.

"There are, however, certain conditions under which the tendency to retardation will cease. It is well known that the penetrating power of short wave-length radiation increases with the frequency. If it be assumed that the penetrating power of ethereal radiation increases as the *square* of the frequency, it can be shown that the increased energy density in front of an isolated particle, due to motion, will be compensated, and the motion continue unchecked. Though more energy density is still encountered by the forward face and less emitted behind, these effects are compensated by the decreased absorption of the radiation encountered in front. A similar compensation occurs for radiation overtaking the particle from the rear, the increased absorption making up for the greater density of

the waves re-radiated in front and the smaller number per second received from behind. Hence while pressure increases on both faces, it increases equally, thus keeping the pressures balanced and leaving the motion unaltered.

"Another interesting consequence follows from the assumption that the penetrating power of ethereal radiation increases as the square of the frequency. Granted this relation, then the energy absorbed increases according to the equation:

$$E' = E \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

where E is the energy absorbed per second by a stationary particle, E' the energy absorbed per second by a particle moving with velocity v, and c the velocity of light.

"The energy re-radiated, like the energy absorbed, is also found to follow this law, the relation in this case being independent of any assumption as to the variation of penetrating power with frequency.

"When an attempt is made to extend the reasoning from the above assumption to an aggregate of particles, however, their mutual reactions result in an aggregate retardation. From this it may be inferred, either that the radiation theory is incorrect, or that some compensating influence, at present unknown, is in operation where material aggregates are concerned."

It is of interest to note that, in the case of an isolated particle, an assumption so simple as an absorption which varies inversely as the square of the frequency should reconcile the radiation theory with the facts of non-retardation in space, and at the same time predict the exact increase of radiation with motion calculated by Larmor and required both by the radiation theory, and by the facts discovered by Kaufmann and Bucherer, on the assumption that matter is composed of radiation. If this is a

coincidence, it is certainly an interesting one. Dr. Snell's results are also in agreement with the assumption that the non-thermal radiation which modern physics more than suspects all matter to be emitting, is absorbed from a radiant ether. For it is a consequence of his assumption, not only that the increased emission shall be exactly that called for by theory, but that the increased absorption shall be exactly that required to supply the increased emission. These combined coincidences suggest that the mechanism of energy supply to radiating materions postulated by the radiation theory is not a mistaken one.

Nevertheless, it must be admitted that the apparent failure of the assumption where aggregates are concerned, like the similar failure in the case of the Lorentz contraction, is a weak spot in the evidence for the radiation theory. Indeed, were it possible to show that failure to be inevitable on any assumption, it would be a refutation thereof. But the chances are that the failure is due to our ignorance of the radiation mechanism, for certain very simple facts about radiation in general make it quite plain that some compensating effect is set in operation under the conditions assumed by the radiation theory, which prevents retardation by Doppler-displacements. Thus assume an enclosed space bounded by walls impervious to heat and occupied by a mass of air or other gas at a high temperature. The molecules of such a gas are moving at high velocities in all directions and exchanging radiation with one another in such a manner as to maintain a condition of dynamic equilibrium. Furthermore, the space between the molecules is filled with radiation moving in all directions, also in dynamic equilibrium with the molecules. In short, such a space is an analogue of that postulated by the radiation theory of matter-occupied

space in general, ethereal radiation taking the place of radiant heat, and materions taking the place of molecules. Now let us assume that Doppler-displacements in such an aggregate of radiating molecules can cause retardation of their motion. What will happen? Obviously the molecules will gradually transmute their kinetic energy into radiant heat or light, their own motion in consequence constantly diminishing, until the air, by the ensuing fall of temperature, assumes a liquid and then a solid form, its kinetic energy having been transformed into radiant heat by the retardation of the molecules due to the Doppler-displacements to which they are subject. Now every physicist knows such a result would not ensue. He knows that the temperature of a gas under the circumstances postulated would in fact remain constant, which means that none of the kinetic energy of the molecules would be lost despite their subjection to Doppler-displacements, both in emitted and in-falling radiation. And if no kinetic energy is lost there can be no retardation. To anyone familiar with the simplest facts of heat exchange no proof of this proposition will be required. Whatever the cause may be therefore, it seems safe to assume that Doppler-displacements in a uniform field of radiation cannot cause the retardation of material bodies. At any rate to assume that they can is contrary to all experience. Nature appears to possess no mechanism for transforming kinetic energy into radiant energy under these circumstances, and this doubtless is why material bodies are not retarded in their motion through space.

Section 10. What is the cause of impenetrability?

This question is raised here principally in the interest of symmetry. With respect to the cause of the other two

fundamental properties of matter, inertia and gravitation, the radiation theory has something definite to suggest, but with respect to the cause of the third, impenetrability, it has little, except to establish a presumption that it is a reaction between radiation and radiation. Confronted with this problem it shares the ignorance of the classical theory in general, an ignorance which the relativity theory does not help to diminish. The radiation theory in fact does not indicate the cause of impenetrability. This property of matter, to be sure, is a function of the constitution of the atom, the electron, or of their constituents. All that the radiation theory can at present suggest is contained in the discussions to be found in Sections 4 and 9. Presumably it is due to a repulsion of some kind between radiations—between standing waves perhaps. It is a short distance repulsion effect contrasting with the long distance attractive effect of gravitation. And we may conjecture that it is due to some correlative radiational cause. Beyond this we cannot venture far, but must trust to future investigation for enlightenment. Failure to provide definite answer to this question is no doubt a weakness of the radiation theory, but it is a weakness which alternative theories share. The cause of impenetrability is a problem which all physical theories have thus far found insoluble.

Section 11. Are verifications of the predictions of the equations of relativity also verifications of the radiation theory?

This question cannot be answered with assurance until the radiation theory has been given much more complete mathematical expression than it has yet received. Pending such expression, however, it may be said that the correc-

tions called for in the formulæ of classical mechanics appear to be of the same general character and order of magnitude in the case of the radiation theory as in that of the equations of relativity. If Doppler-displacements in wave-trains moving with the velocity of light are at the bottom of the deviations from classical laws, the departure from classical formulæ would be inappreciable at velocities very small compared to that of light, and become pronounced only when velocities such as those observable in cathode ray electrons are attained. This coincides with the requirements of the radiation theory, the relativity equations and the facts. Whether mathematical expression of the radiation theory would result in equations identical with those of relativity in all cases cannot be either affirmed or denied at present, but the presumption is that they would not. This presumption arises from evidence presented elsewhere that the relativity equations are probably over-simplified and incomplete dimensional disguises for the Doppler-displacements required by the radiation theory. They do not for example distinguish between primary, secondary and tertiary displacements, and hence at high velocities would not predict the last two.

Recently rather grave doubt has been cast on the contention of the relativists that the general theory has received quantitative verification from the facts. At a meeting of the Optical Society of America at Ithaca, N. Y., Oct. 25, 1929, three papers were presented which discussed the three well-known phenomena alleged to have yielded quantitative verification, and the judgment of the authorities presenting them is adverse to such allegation. Thus with regard to the alleged verification by the bending of stellar light rays by the sun, Poor says:

"The actual stellar displacements, when freed from all assumptions, do not show the slightest resemblance to the

predicted Einstein deflections: they do not agree in direction, in size, or in the rate of decrease with distance from the sun."[48]

With regard to the alleged verification by the shift of spectral lines toward the red in strong gravitational fields, Burns, after affirming that at the solar surface "the predicted Einstein shift to the red will be twenty-one parts per ten million," concludes his examination of the evidence as follows:

"Although several text books are teaching our beginners that the proof of the red shift rests on at least as firm a foundation as that of the law of gravity, the writer thinks that the scientific mind does not usually accept as clearly proven a thesis whose proof requires the sort of treatment of the observational data that is necessary to bring the red shift of all solar lines to exactly twenty-one parts per ten million."[49]

Lastly, with regard to the alleged verification by the motion of the perihelion of Mercury, Morgan, after pointing out that the most recent calculations indicate a residual motion (unexplained by the classical equations) of 50.9 seconds per century, notes that the relativity prediction of 42.9 seconds per century fails of quantitative verification, in the following words:

"The Relativists are definite in stating that the Einstein theory calls for certain motion in the perihelia only without explanation of residuals in the eccentricities or orbit planes. Abstracting the Einstein motion of 42.9″ from the above residual for Mercury still leaves a residual four times its probable error."[50]

The question of quantitative verification is one for

[48]Poor, C. L., *Journal of the Optical Society of America,* vol. 20, p. 211.

[49]Burns, Keivin, *ibid.,* p. 224. [50]Morgan, H. R., *ibid.,* p. 228.

experts to decide. There is disagreement among them, and no attempt can here be made to judge between the contending claims. Perhaps the most that can be safely said is that the facts disclose a deviation from the classical laws of physics, related in some way to the relative motion of bodies and their gravitational fields, of a magnitude approximated by the predictions of the relativity equations. This being the case, it seems reasonable to assume that these deviations are due to the nature of the forces acting between bodies. Neither the classical physicists nor the relativists assume anything specific about the nature of these forces, but the tacit assumption of the former that they act with virtually infinite velocity, and hence require no correction for relative motion, appears to be unsound. Moreover, the highly suggestive relation of these deviations to the velocity of light suggests that causal impulses moving with that velocity constitute the "forces" postulated by physics, and hence corrections of a magnitude related to this finite velocity are called for. The radiation theory, indeed, specifically assumes that these causal impulses are due to radiation having the normal velocity thereof, and hence are subject to the variation with motion to which all radiation is subject, thus accounting, qualitatively at least, for the physical significance of the relativity equations. The confirmation of these equations by the facts, even when only approximate, therefore, would appear to constitute confirmation of the radiation theory also, though this cannot be said without reservations. In the more complex cases, indeed, especially in those involving gravitation, it is difficult to come to definite conclusions until the radiation theory has received the mathematical expression which alone can disclose its predictions in quantitative form.

Section 12. Is gravitation due to longitudinal radiation?

In Section 1 Einstein's assumption that gravitation moves with the velocity of light was adopted as a probable hypothesis; nor have any facts tending to invalidate that assumption been disclosed in subsequent sections. Nevertheless it is not the only hypothesis consistent with the facts as at present known, and perhaps not the most probable one. That the velocity of gravitation may not be the same as that of light is implied by Eddington, who says:

> "It is presumed that the speed [of gravitation] is that of light, but this does not appear to have been established rigorously."[51]

In view of the uncertainty of the velocity of gravitation, a variation of the assumptions specified in Section 1 will here be suggested which appears to be less arbitrary perhaps, and to fit in with certain apparently unrelated and baffling facts of physics in a manner which may turn out to be significant.

It has already been noted that space behaves in certain respects as if it were an elastic solid. If so it would not be unreasonable to expect that it might behave similarly in certain other respects. Now it is well known that when transverse waves, such as those of light, are set up in an elastic solid, longitudinal waves, vibrating like sound in a direction coinciding with the direction of propagation, are set up also, and unless the solid is absolutely incompressible, these longitudinal waves will have a finite velocity, though a higher one than the transverse waves.[52] One of

[51]Eddington, A. S., *The Mathematical Theory of Relativity*, pp. 147, 148.
[52]See Green, George, *Mathematical Papers*, p. 246.

the baffling mysteries of the undulatory theory of light has been that these longitudinal waves have never been detected though carefully looked for, and the conclusion of those who have advocated the elastic solid theory has been that the ethereal medium so nearly approaches incompressibility that these longitudinal waves move with a velocity so high and a penetrating power so great as to be undetectable by physicists. On this assumption the mystery disappears. Of late years, to be sure, the electromagnetic theory of light has largely displaced the elastic solid theory, but it solves the mysteries of the latter theory only by ignoring them. Its equations, which indeed constitute the theory, offer no explanation of the transmission of transverse vibrations by space, or of the apparent absence of longitudinal ones.

That the electromagnetic theory, however perfect as a mathematical representation, affords no true explanation of these phenomena, is emphasized by Michelson, as follows:

> "Beautiful as it [the electromagnetic theory] is, and powerful as a means of accounting for the various phenomena of light, it may be well to point out that it is in fact no explanation at all, in the sense of reducing the phenomena to more familiar types. Indeed, in this respect the elastic solid theory has all the advantage. For some sort of medium is required for the propagation of electromagnetic disturbances, and the properties of such a medium cannot be 'explained' on any but mechanical concepts."[53]

Moreover, as Wood says—"This 'elastic solid' theory . . . can still be used to advantage in treating many optical phenomena, for it is more easily intelligible than the mod-

[53]Michelson, A. A., *Studies in Optics,* 1927, pp. 4, 5.

ern electro-magnetic theory."[54] And if we examine the most modern theory of all—that of wave mechanics—we shall find that it is engaged in interpreting the laws of mechanics themselves in a manner tending to remove another difficulty of the elastic solid theory in the manner described in Section 9. In fact this theory shows signs of rejuvenation, but whether rejuvenated or not, we can, indeed we must, at least assume that space acts much "as if" it were an elastic solid, and on that basis may perhaps detect the long-missing longitudinal radiation which belongs in space and the explanation of gravitation at the same time. We do not of course assume that gravitation is caused by the longitudinal waves associated with ordinary light and radiant heat—they would be far too feeble to cause an effect of the magnitude observable. But we may with considerable plausibility assume that the *G*-radiation postulated in Section 1 is simply a longitudinal form of radiation arising from the changed constitution of space associated with materions. This changed constitution would appear to be a decreased compressibility of the ethereal medium as compared to non-material space, causing, on re-radiation, a slight transformation of transverse into longitudinal radiation, and thus a deficit of pressure-producing power from each materion. On the assumptions postulated, theory would appear to require that such a transformation should occur, and this agrees with the facts of gravitation. If this surmise is correct, the rate of speed at which the gravitational impulse radiates from a materion must be much greater than that of light, as great perhaps as the speed assumed by Laplace. But the velocity of the radiation which results in the actual change of motion of material bodies, due to said impulse, would still be the same as that of other transverse vibrations,

[54]Wood, R. W., *Physical Optics*, p. 3.

being due—for the most part at least*—to the less penetrating transverse radiation re-radiated as *I*-radiation. At any rate, this appears to be the way the theory would work out, and this variation of the radiational theory of gravitation is suggestive of the facts as we find them. For if it is sound, electromagnetic effects are due to transverse vibrations, and may be of two kinds, corresponding to clockwise and counter-clockwise polarization, as suggested in Chapter VIII, whereas gravitation is of one kind only because due to longitudinal vibration, which is incapable of polarization.

Another feature of this method of explaining gravitation may be noted here. It is known that the rate of transmutation of transverse into longitudinal radiation, and *vice versa,* is determined by the constitution of the medium through which the radiation is propagated.[55] And if we assume that the transmutation of transverse into longitudinal radiation by re-radiation from materions is subject to reversal throughout the universe by a gradual re-transmutation of longitudinal into transverse radiation by propagation through the ethereal medium, we shall be provided, not only with the solution of a mystery which has long beset cosmological theory (see Section 14), but shall arrive at a conclusion independently arrived at by Einstein, namely, that the gravitational constant is determined by the total amount of matter in the universe. For

*The in-falling longitudinal radiation would produce the same effect as the transverse, though its variation with motion of the gravitating body would bear no significant relation to the velocity of light. Were it possible to attribute the whole gravitational effect to this form of radiation—and we cannot confidently assert that it is not—the peculiar deviation of moving gravitating bodies from the Newtonian law would then have to be attributed to their variation of inertia with motion. And this, indeed, would seem to be adequate to account for the deviation, at least qualitatively.

[55]See Stokes, G. G., "Report on Double Refraction," *Report of British Association for 1862,* p. 257.

it plainly follows from the assumptions here made that the greater the proportion of matter to non-matter in space, the greater the amount of longitudinal radiation which will pervade it, and it is this proportion, together with the absolute intensity of the ethereal radiation, which determines the gravitational constant. This to be sure is a very different theory from that of Einstein (see page 248) and involves no non-Euclideanism, but it agrees with his theory so far as the dependence of the gravitational constant on the density of matter in the universe is concerned.

Still another resemblance between Einstein's speculations and the present one seems worth pointing out. On pages 80, 81 it will be noted that, according to Einstein, inertia is a function of temperature, and on page 230 that inertia and gravitation are the same thing. From which it follows that gravitation, according to Einstein, is a function of temperature. We have seen how and why the radiation theory coincides with the view that inertia is a function of temperature (page 100), and if gravitation is attributable to longitudinal vibrations of the character specified, gravitation will be so also, since light and radiant heat, which are themselves functions of temperature, will be accompanied by longitudinal vibrations also, the effects of which will be of the same nature as *G*-radiation, albeit of much feebler intensity, and doubtless of less penetrating power, as in the case of the corresponding transverse vibrations. It is obvious, indeed, that on the assumptions, both of the relativity and of the radiation theory, the inertial and gravitational effects of temperature are too small for detection by methods known to physicists, but it is interesting to note the coincidence in consequences of the two assumptions, although it is clear that there are dis-

tinct differences also. The radiation theory, for instance, would deny that inertia and gravitation are the "same thing."

It may be conceded that the guess here recorded as to the cause of gravitation is speculative, but its tendency to reconcile a series of cosmological mysteries and inferences, would seem to justify its proposal. It is obvious that the radiation theory does not stand or fall with these assumptions, but they appear to fit in well with the elastic solid theory, which after all is the only theory that explains the transmission of light through space. At the same time they avoid the suggestion of arbitrariness attaching to the assumptions of Section 1. For these reasons it has seemed worth while to present them as a variation which, through more careful examination, may perhaps prove fruitful in affording further insight into the mechanism of the cosmos.

Section 13. What is the cause of light?

An interesting consequence of the theory of inertial mass expounded in this chapter is that change of motion of material bodies involves creation of mass when the change is a positive acceleration relative to the ether, and destruction thereof when it is a negative acceleration. That is, energy and mass leave the body together during retardation, just as Tolman on page 125 alleges, and return to it during acceleration. And as it is all a matter of energy exchange due to changes in Doppler-displacements, it is a relativity effect, as he alleges also. Thus the destruction and creation of mass, contrary to the views held a generation ago, is a very familiar and every-day phenomenon, occurring at every swing of the pendulum, but inter-

preted aforetime as the conversion of kinetic into "potential" energy, and *vice versa*.

Now it is of interest to raise the question of the form taken by the energy (and hence the mass) which leaves a material body when it is subject to retardation. Evidently a pulse of radiation is emitted by the body during the interval of change of motion, and this pulse takes the form of a spherical shell of radiation moving from the retarding body in all directions with the velocity of light, but, owing to the dissymmetry of the Doppler-displacement, of markedly different wave-length in different directions. Not only will such a shell of radiation originate from the emitted radiation, but the transmitted or refracted radiation will be affected likewise, and radiate a similar shell, which, by interference with the accompanying untransmitted radiation, will presumably give rise to secondary beat waves of much lower frequency than those from which they originate. These secondary waves also will be of markedly different wave-length in different directions, being a minimum in directions coinciding with the direction of retarded motion and infinite at right angles thereto. The duration of this pulse will be smaller and its intensity greater in proportion to the suddenness of the retardation. Hence, other things being equal, the slower the retardation of the body, the more the radiation will depart from a sudden pulse and approach continuous radiation. That is, the departure of the radiation from continuity will be greater the shorter the wave-length. Can this be the cause, or at any rate one cause, of light? If so, light, if not identical, is associated with that portion of the mass of an electron thrown off when it is suddenly retarded. The facts of modern physics indicate that light is emitted from a radiating source in

pulses of this general character, and that it arises when very small bodies—in the case of visible light and X-rays, electrons—are subject to rapid change of velocity. Should the surmise that this is the origin of light turn out to be valid, it would seem that the radiation theory is qualified to make a beginning at least in the explanation of the facts which have given rise to the quantum theory. The subject, however, is a very difficult and complicated one, and no effort will be made to follow it up in this volume. But some significant facts, especially facts of interference, seem to support such a surmise. Among them the experiments of Erwin Schrödinger appear to be particularly suggestive. These are described in the *Annalen der Physik,* vol. 61, 1920, pp. 69–86, in an article entitled "Uber die Koharenz in weitgeoffneten Bundeln." They indicate that the possibility of interference between light rays is dependent in an interesting way upon the relative direction in which they leave the common source. The classical undulatory theory would seem to predict that interference would not be a function of direction. At least no reason why it should be is suggested by that theory. The usual quantum theory, on the other hand, which pictures light as due to something in the nature of corpuscles or "bullets" of radiation, would require exact coincidence of direction between rays capable of interfering, if indeed interference is compatible with the theory at all. The theory of light here put forth, on the other hand, would suggest that interference will occur if the rays leave the source in a direction approximately the same, but will become more imperfect as they depart from coincidence of direction, because of the dependence of wave-length in the shell upon direction. At just what angle interference effects would completely disappear cannot be stated with-

out rather elaborate investigation, and in any event would depend, among other things, upon the sensitiveness of the instrument used to detect the effect. Now Schrödinger's results, owing to experimental difficulties, were not very satisfactory, but he was able to observe interference fringes between rays leaving a source at considerable angles, though the interference became less distinct as divergence from coincidence of direction increased, the maximum divergence of the rays at which it was possible to observe fringes being about 57°. There is much uncertainty about the bearing of these experiments on the above speculation about the origin of light, but they would on the whole appear to favor it. At any rate, they seem to refute completely the quantum theory in its extreme "corpuscular" form, as indeed, many other interference experiments do.

The only other experiment, bearing on this particular point, of which I have knowledge is one in which an attempt was made to cause two rays to interfere, one (A) proceeding directly from the source, and the other (B) starting in the opposite direction, but reflected so as to coincide in direction with (A) by a mirror placed close to the source. The result showed no interference.[56] So far as it goes then, this experiment confirms Schrödinger's results and the theory proposed in this section.

The pulses observable by human beings as light are, in any event, not unchanged ethereal radiation, but of secondary forms of much lower frequency, which may have the origin suggested. But whatever their origin may be, it is at least suggestive that they are associated with sudden changes of velocity in bodies which, on independent grounds, are known to be emitters, and presumably

[56]See Wood, R. W., *Physical Optics*, p. 147.

transmitters, of radiation, and hence would necessarily give off radiation pulses on retardation. While this is a speculation subject to certain serious objections, it appears worthy of notice, at least as a query.

Section 14. What becomes of star-light and gravitation?

It may seem odd to raise the question of the fate of star-light and gravitation at the same time, but if the radiation theory is sound, these two questions belong together, since they both relate to the behavior of radiation which differs in some respect from the normal ethereal radiation of space, the former being a less, and the latter due to a more, penetrating kind. And it is perhaps of some significance that these two questions are found to be associated, even by those who do not entertain the radiation theory. The two questions, for instance, are discussed together by Einstein under the title "COSMOLOGICAL DIFFICULTIES OF NEWTON'S THEORY," as follows:

"If we ponder over the question as to how the universe, considered as a whole, is to be regarded, the first answer that suggests itself to us is surely this: As regards space (and time) the universe is infinite. There are stars everywhere, so that the density of matter, although very variable in detail, is nevertheless on the average everywhere the same. In other words: However far we might travel through space, we should find everywhere an attenuated swarm of fixed stars of approximately the same kind and density.

"This view is not in harmony with the theory of Newton. The latter theory rather requires that the universe should have a kind of centre in which the density of the stars is a maximum, and that as we proceed outwards from this centre the group-density of the stars should diminish, until finally, at great distances, it is succeeded

by an infinite region of emptiness. The stellar universe ought to be a finite island in the infinite ocean of space.

"This conception is in itself not very satisfactory. It is still less satisfactory because it leads to the result that the light emitted by the stars and also individual stars of the stellar system are perpetually passing out into infinite space never to return, and without ever again coming into interaction with other objects of nature. Such a finite material universe would be destined to become gradually but systematically impoverished."[57]

Dr. Hubble of the Mt. Wilson Observatory also raises these two questions together in much the same way and to the same effect, as follows:

"In the absence of internebular absorption, a uniform distribution of equally luminous nebulæ would eventually produce a luminous background to the sky. No such phenomenon is observed. Moreover, it is well known that Newton's law of gravity cannot be reconciled with an infinite universe unless the latter is constructed in a very special manner."[58]

Again, Dingle associates the two questions in a manner very suggestive when we consider, as we presently shall do, how this problem bears upon the issue of dynamic vs. static space. Thus he says:

"It is easily seen that if the stars were uniformly distributed throughout an infinite volume, then, if there were no sensible absorption, their light would appear infinitely bright."[59]

After giving the mathematical reasons for this conclusion he proceeds:

"This line of reasoning is open to the objection that most of the light might be absorbed in its journey through

[57]Einstein, A., *Relativity*, pp. 105, 106.
[58]Hubble, E., *Science News-Letter*, vol. 2, p. 113.
[59]Dingle, H., *Modern Astrophysics*, p. 163.

space, so that the amount we experience gives no evidence on the question. We can, however, apply the argument in a slightly different form. Its essential feature is that, as the sphere grows, the number of stars included increases as the cube, while the light received from them decreases only as the square of the radius. If, now, the stars emit anything other than light, which obeys the same inverse square law, then that something will answer our purpose just as well as light. Now the stars are believed to exert gravitational attraction; *i. e.*, they emit gravitational lines of force, which satisfy our conditions absolutely. If there were an infinite, uniform distribution of stars, the gravitational lines of force reaching the Earth would be infinite in number. But they are not. Hence we conclude again that the stars are not spread uniformly throughout infinite space.

"But the matter is not yet quite beyond doubt. Even if we grant the assumption that matter everywhere obeys the Newtonian law of gravitation, we are still faced with the possibility that gravitational lines of force might be absorbed in space. . . . Majorana has brought forward experimental evidence which he claims establishes the fact of such an absorption. Whether this be so or not is still an open question, but the possibility cannot be ignored. As a rigid proof of the limited extent of the Universe, therefore, this argument falls over the same obstacle as did the last."[60]

It is apparent from this passage that Dingle perceives the flaw in the reasoning of Einstein, and that in his recognition of an alternative to the latter's conclusion he is unconsciously postulating the radiation theory, or at any rate *a* radiation theory. But before presenting this alternative as the radiation theory provides it, let us turn to the way out of the difficulty proposed by Einstein. This is expounded by him in Sections 31 and 32 of *Relativity*. Briefly, it amounts to this: Space is "curved," and

[60] *Ibid.*, pp. 163, 164.

thus the universe is a closed space, analogous to the surface of a sphere. As the latter two-dimensional magnitude is unbounded, though finite, so also is the former three-dimensional magnitude. Whether the curvature of this finite universe is "spherical" or "elliptical" is somewhat doubtful it seems, but it would, according to Einstein, "necessarily" be one or the other if matter is distributed uniformly. But he adds:

"Since in reality the detailed distribution of matter is not uniform, the real universe will deviate in individual parts from the spherical, *i. e.*, the universe will be quasi-spherical. But it will be necessarily finite."[61]

Thus as the universe is not infinite, no infinite gravitational field would be found in it, and this, according to Einstein, saves Newton's law of gravitation from the difficulty described in the passage just quoted. It also provides a way out of the difficulty about the fate of starlight and the universal illumination of space, since the light of the stars is not lost in infinite space, as it would be in an "uncurved" universe, but simply follows the curvature of space and comes back to its starting point, starts all over again, and continues its "universe-trotting" indefinitely. Thus it is never lost, yet is always localized in a star, or a "ghost" of one, that is, in a point where a star once was. Hubble evidently regards this as a satisfactory solution of the two difficulties, his comment being as follows:

"The general theory of relativity . . . avoids both of these difficulties by postulating a universe which is finite though boundless. . . .

"Even now we are observing [with the 100 inch reflec-

[61] *Relativity*, p. 114.

tor at Mt. Wilson] an appreciable fraction of the Einstein universe."[62]

Eddington, on the other hand, has a low opinion of this *solution. In fact,* he tells us that it violates the principle of *relativity.* Thus he says:

"It appears to have been overlooked that Einstein's new hypothesis is inconsistent with relativity in its ordinary sense. . . .

"We regret being unable to recommend this rather picturesque theory of anti-suns and anti-stars. It suggests that only a certain proportion of the visible stars are material bodies; the remainder are ghosts of stars, haunting the places where stars used to be in a far-off past.

"Owing to this violation of the restricted principle of relativity we have a feeling that Einstein's new hypothesis throws away the substance for the shadow."[63]

The fact is that Einstein's conclusions about the "cosmological difficulties of Newton's theory" are baseless, because inferences which follow from the postulation of conditions at points infinitely remote from the sun have no standing in science. No conclusions of any value can be obtained from them. And to assume that the laws of gravitation or light propagation would obtain there as here, and to base physical conclusions on the assumption is not reasonable. If a chemist were to take a single grain of sand from a beach, analyze it, find it to consist of silica, and from this sampling conclude that the whole earth is composed of silica, it would be generally agreed that he was a person intemperately addicted to generalization. But he would have better grounds for his inference than those who attempt to judge of what conditions at infinity are,

[62]Hubble, E., *Science News-Letter,* vol. 2, p. 113.

[63]Eddington, A. S., *Report on the Relativity Theory of Gravitation,* p. 87.

or would be, from samples observable in the humanly visible universe, no matter what the size of the telescope used.

But even assuming we could have knowledge of conditions at infinity, Newton's law of gravitation can be refuted by such reasoning as Einstein's only if we assume it to be a mathematical law which holds absolutely and everywhere. There is no evidence that any physical law is of this character, and even if it were, human beings would be unable to recognize the fact, because observational powers of absolute precision would be required and men have no such powers. The radiation theory, of course, is subject to no such difficulties as those raised by Einstein and Hubble, and need not resort to an unintelligibility like "curved space" as a substitute for an explanation of the absence of an all-pervading illumination or an infinite gravitational field. It simply recognizes the law of gravitation as a normal physical law, which in all probability is not mathematically exact. Its departure from exactitude might be due to many causes, but on our assumption one of these at least is the absorption of *G*-radiation in space and its ultimate conversion into normal ethereal radiation. We do not know the rate of this conversion, but so long as it is finite, what happens at infinity does not concern us. Nobody knows what happens there and conjecture is futile.

The other difficulty raised by Einstein and Hubble is just as readily disposed of. We simply have to assume, what after all is very reasonable, that the non-absorption of light in space is not an absolute. In short, light, like *G*-radiation is gradually converted into ethereal radiation in its passage through space, and hence does not go on forever and disappear from the universe never to return.

A static ether, or an empty space, to be sure, could not absorb it, since there would be no form of energy possible therein, into which it could be converted; but this difficulty does not confront the radiation theory. If that theory is sound neither star-light nor gravitation extend to infinity, though no doubt they travel a long way, and thus the problem of their fate, apparently insoluble on the theory of a static ether or an empty space, finds a plausible solution.

Moreover, it will be noted that this is the solution implied by Dingle in the passage already quoted. The absorption there referred to as the alternative to Einstein's explanation would be impossible if space were static. Thus Dingle tacitly assumes a radiation theory, just as we find that Tait and Preston and Thomson and MacDonald and Einstein and Lewis and Tolman do, for quite different reasons; and just as we shall find Millikan doing in the section following. Hence the explicit answer of the radiation theory to the question: "What becomes of star-light and gravitation?" is one found to be implicit, or at least adumbrated, in the assumptions of many physicists.

Section 15. Are conditions favoring the destruction and creation of matter present in the universe?

Modern speculation concerning the origin of stellar energy has led to the conclusion that most of it is due to the conversion of matter into radiation, according to the equation $E = mc^2$. This will give 9×10^{20} ergs of radiant energy for every gram of matter destroyed, and Jeans calculates that from this cause "the sun's total mass is diminishing at about 250,000,000 tons a minute."[64] There

[64] Jeans, J. H., "The Physics of the Universe," *Nature Supplement*, Nov. 3, 1928, p. 697.

is general concurrence among physicists in this theory, and if it is a sound one, it follows that conditions favoring the destruction of material particles are present in the stars. What these conditions are is not known, except that a very high temperature seems to be one of them. There is at any rate no positive evidence that destruction occurs at low temperatures, or indeed elsewhere than in the interior of stars, where the temperature (and pressure) conditions are, obviously, so extreme as to be unreproducible in the laboratory. The radiation theory offers no further clue to these conditions. It would, doubtless, attribute the destruction of matter to unbalanced radiation pressure of some kind, presumably of some extreme degree, but affords no hypothesis about the origin thereof. There is, in fact, no theory of the cause of the conversion of material particles into radiation at present available to physics.

Now our sun is rather an old and a small star, as stars go, and if it is losing mass at the rate of 250,000,000 tons a minute, at what rate are the larger and hotter stars losing it? Obviously at a much higher rate. And this suggests the question: How long has this thing been going on? The age of the stars is not known with any precision, but Jeans estimates their average age as "from 5 to 10 millions of millions"[65] of years. Hence if there is no creation of matter to compensate for this continual destruction, the question arises: Why has not all the matter in the universe been converted into radiation long ago? Of course, as the suns radiate energy, getting smaller and smaller, they will eventually cool down to a temperature where the destruction of matter ceases, or practically ceases, achieving some such condition as is found in the

[65]Jeans, J. H., "The Wider Aspects of Cosmogony," *Annual Report of the Smithsonian Institution,* 1928, p. 171.

moon, but evidently no such condition has yet been attained, or even remotely approached. The blazing stars of space afford ample evidence that there is still plenty of matter in the universe in a condition ripe for destruction.

One explanation of this would be that if we should go back a few billion years in the history of the universe, we should encounter a time when conditions were very different. We should witness a "beginning" of the present regime of blazing suns and disappearing matter perhaps. And I know of no way of disproving this hypothesis. Perhaps it is the explanation of the mystery. But such an hypothesis would involve the assumption that present physical laws and conditions, at least those affecting radiation and matter, are entirely different now from what they were then, and this, though an admissible, is a somewhat arbitrary assumption. There are certainly no facts on which to base it except the difficulty of explaining the present cosmic situation in any other way. But another explanation is entirely possible, and this is that there are in the universe conditions favorable to the creation of matter. Moreover, this hypothesis would seem to involve no such arbitrary assumption as the other explanation. It would not require us to postulate a fundamental change in physical laws, due apparently to the mere passage of time. It would not require us to assume that these laws were entirely different a few billion years ago from what they are now. This is a highly speculative question and no confident answer to it is possible, but it is a question about which the radiation theory has something to say, and that is why we have raised it.

There are two views held by present-day physicists on this issue. The one view holds that the conversion of matter into radiation is not reversible and hence that the

material universe is fated to disappear by conversion into ordinary radiation. The other is that the conversion is reversible by a compensating conversion of radiation into matter. These contrasting views are held respectively by two eminent physicists. Jeans holds to the former, and Millikan to the latter, and perhaps no better presentation of the two hypotheses and their relation to the radiation theory can be given, than by contrasting the views of these two physicists. It must be understood that both of them regard the ether and the universe as static. That is to say, neither of them postulate the radiation theory.

Jeans' views will be found epitomized in his article on "The Physics of the Universe"[66] and the following account of the non-reversible theory of matter destruction is taken from that article. Thus he informs us very definitely that "Space, regarded as a receptacle for radiant energy, is a bottomless pit" (page 698). In other words, the radiation flowing out of the suns of space falls into the "bottomless pit" thereof and forever disappears—whither we know not. This radiation is in the familiar form of light and radiant heat, essentially the radiation which inhabitants of the earth receive from the sun, and this includes no waves short enough to reconvert radiation into matter. Jeans maintains the current hypothesis that matter is converted into radiation in the interior of stars, and to a less extent perhaps even in cold bodies, but as he can find no place in space where conditions favorable to the reconversion of radiation into matter can occur, he concludes that no such reconversion is possible. He says:

"Thus the transformation, mass → radiation occurs everywhere, and the reverse transformation nowhere.

[66]*Nature Supplement,* Nov. 3, 1928.

There can be no creation of matter out of radiation, and no reconstruction of radioactive atoms which have once broken up. The fabric of the universe weathers, crumbles, and dissolves with age, and no restoration or reconstruction is possible. The second law of thermodynamics compels the material universe to move ever in the same direction along the same road, a road which ends only in death and annihilation" (page 698).

Jeans, like all reasonable physicists, gives up the attempt to discover how matter originally came into being—he has no hypothesis about the beginning of things—but he recognizes the probability that if radiation of a wave-length of 1.3×10^{-13} cm. were present in space, matter could be created, for he says, referring to processes for the creation of matter:

"The temperatures necessary to effect the processes . . . are so high that, to the best of our knowledge, they are not to be found anywhere in the universe. . . . If we want a naturalistic interpretation of this creation [of matter], we may imagine radiant energy of any wave-length less than 1.3×10^{-13} cm. being poured into empty space; such radiation might conceivably crystallise into electrons and protons, and finally form atoms" (page 698).

Thus the only reason for Jeans' conclusion that the conversion of radiation into matter cannot occur is that he can find no temperature in space high enough to yield radiation of the necessary frequency. But he does not consider the possibility that the radiation may, like the radiation of radium for instance, be of a kind independent of temperature. Yet if such radiation were present, what means would he have of being observationally aware of it? None at all, of course. Hence the absence of temperatures required for generating radiation essential to the creation

of matter does not necessarily involve the absence of the radiation. Were it present all around him, he would be unaware of the fact, as much so as of the radio waves which surround him, in the absence of receiving apparatus sensitive to them. He perceives the gravitational and electromagnetic behavior of bodies to be sure, but he does not recognize them as effects of radiation. He does not know, or even assume, what they are effects of. But the radiation theory does assume, and if the assumptions of that theory are sound, Jeans' conclusions about the absence from the universe of radiations of frequency high enough to convert radiation into matter, and thus compensate for the conversion of matter into radiation in the stars, rest on inadequate premises. Temperature is not necessarily the only source of radiation of wave-length less than 1.3×10^{-13} cm. and any physicist who so assumes is likely to be misled. So much for the reasoning of Jeans. It is at least not conclusive. Let us now turn to that of Millikan, who typifies the opposite view.

In an article on "The Origin of the Cosmic Rays" appearing in the *Physical Review* for October, 1928, Millikan, with Cameron as co-author, presents certain reasons for believing that the so-called cosmic rays owe their origin to the formation of helium, oxygen, silicon, and perhaps iron, out of hydrogen. By means of evidence which it would be irrelevant to cite or to evaluate here, he further concludes that atom building of the type thus exemplified "is a phenomenon which, in some as yet unknown way, is favored by the extreme and thus far unexplored conditions of *low temperature and density* existing in interstellar space" (page 550). And that "the main *atom-building processes probably do not take place inside of stars at all*" (page 552). And these conclusions in turn

suggest to him "the following incomplete cycle each element in which now has the *experimental* credentials indicated in the brackets" (page 554). He then proceeds:

"(1) Positive and negative electrons exist in great abundance in interstellar space (see the evidence of the spectroscope).

"(2) These electrons condense into atoms under the influence of the conditions existing in outer space, viz., absence of temperature and high dispersion (see the evidence of the cosmic rays).

"(3) These atoms then aggregate under their gravitational forces into stars (see the evidence of the telescope).

"(4) In the interior of stars, under the influence of the enormous pressures, densities and temperatures existing there, an occasional positive electron, presumably in the nucleus of a heavy atom, transforms its entire mass into an ether pulse the energy of which, when frittered away in heat, maintains the temperature of the star and furnishes most of the supply of light and heat which it pours out (see the evidence of the lifetimes of the stars—Eddington-Jeans).

"The foregoing is as far as the experimental evidence enables us to go, but the recent discovery of the second element of the above unfinished cycle, namely that the supply of positive and negative electrons is being used up continually in the creation of atoms the signals of whose birth constitute the cosmic rays, at once raises imperiously the question as to why the process is still going on at all after the eons during which it has apparently been in process—or better *why the building stones of the atoms have not all been used up long ago.* And the only possible answer seems to be to complete the cycle, and to assume that these building stones are continually being replenished throughout the heavens by the condensation with the aid of some as yet wholly unknown mechanism of radiant heat into positive and negative electrons" (page 554).

Thus we see that, according to Millikan, the annihilation of atoms which goes on within the stars is compensated by a creation of atoms without them. Hence the "transformation mass $\rightarrow$ radiation," which Jeans says is irreversible is, if Millikan's conjectures are correct, balanced by a transformation radiation $\rightarrow$ mass, which renders the process reversible. So far as matter is concerned, therefore, Millikan's hypothesis, if sound, provides the universe with a reversible system, and we are not forced to the hypothesis of cataclysmic change involved in the assumption of Jeans.

But there is a missing link in Millikan's reasoning, and Jeans has pointed it out. The diffused radiant heat and light of the interstellar spaces cannot be condensed into positive and negative electrons, because radiation in a condition to condense into matter must have a wave-length of at most 1.3×10^{-13} cm.; at least we have Jeans' authority for this. Star-light is certainly not of this character. Moreover, if a gram of matter emits 9×10^{20} ergs of radiation during the time of its destruction, then that amount of radiation must be absorbed during the time of its creation. Unless then we assume the creation of matter to be a far more diffuse process than its destruction, this calls for an enormous concentration of radiation at the point where the creation occurs, and diffused star-light, such as fills the interstellar spaces—the kind we perceive on a clear moonless night—is certainly not concentrated. As the latest revisers of Young's *Manual of Astronomy* remark:

"No one has suggested any means by which enough energy to re-form an electron or a proton, or both at once, could be collected, approximately at one point, out of the

feeble and diffused radiation which traverses interstellar space."[67]

We are, to be sure, too ignorant of the subject to deny categorically that light and radiant heat in this diffuse condition might condense into matter, but there is certainly no direct evidence for it, and, according to Jeans, even if the concentration were sufficiently high, the frequency would not be.

If the radiation theory is sound, however, this link in the chain of Millikan's reasoning is no longer missing. If matter fails to be created in the interstellar spaces, it will not be for lack of concentration of radiation there, or radiation of too low a frequency. Millikan's reasoning, in fact, calls for a radiation theory of some kind, just as Einstein's and Tait's reasoning does (see Sections 5 and 7). The theory proposed in this work, in fact, would supply Millikan's "as yet wholly unknown mechanism of" radiation, Tait's "as yet unexplained or rather unimagined" dependence of potential energy on motion, and Einstein's missing potentiality of mass-increase for moving matter, and supply them all by the same general postulate, nor is any straining or distortion of the theory required to do so.

The radiation theory then, does not predict either the destruction or creation of material particles, but if such destruction and creation does occur, by means of the transformations which Einstein's theory of the relation between matter and radiation calls for, then one of the conditions required for the creative side of the process, and probably for both sides, is a radiant ether—a dynamic space. Whether other conditions favoring the processes are

[67]Russell, Dugan and Stewart, *Astronomy*, vol. 2, p. 931.

present in the universe is a question which other evidence must settle.

Section 16. Is the universe reversible?

It may be pointed out that even if the answer to the question propounded in the last section could be shown to be in the affirmative, it would not settle the question of the reversibility of the universe. For that reversibility hinges upon the question of whether the second law of energy (thermodynamics) is universally valid, and whether the universe behaves like an isolated system. The second law informs us that no isolated system is reversible, and no exception to this, or any other requirement of the law, has thus far been discovered. We may, of course, assume that the stellar universe is an exception to the law —at any rate no signs of its running down have been observed—but there is no way of proving that it is an exception. Our only evidence that it is arises from the fact that it is still running, and this is not satisfactory evidence, since its adequacy hinges upon the question of a possible beginning of the present order of things, which is itself unanswerable. Moreover, the question of whether the universe is an isolated system, or behaves like one, is also unanswerable. Whether the universe is reversible or not then is a question to which no confident answer can be given. It is possible, nevertheless, to present evidence that those who confidently assert that it is not, and that the cosmos is consequently travelling toward an eternal quiescence, have no very sound basis for their assertion.

In the first place, even if it could be shown that the answer to the question raised in the last section is in the negative, and that matter is permanently disappearing from the universe, it would not prove that the final stage

of the universe is complete changelessness, or that there is to be any final stage. It would prove that energy in the form of matter is doomed to dissipation, but not necessarily energy in all forms. This would reduce the universe to nothingness for human beings, to be sure, but such beings are doubtless ephemeral products of the universe in any event, and their restricted capacity for the observation of change does not apply to the universe. There is a tendency among speculators to limit the possibilities of the universe by the observational powers of man, which is as unjustified as to limit them by the powers of observing possessed by an oyster or a mole. Such an anthropocentric view of things is misleading. There are doubtless many forms of energy interchange disassociated from matter, and forever beyond the power of human observation. Human powers of inference, however, can suggest their existence, and even reveal evidence for the existence of some of them. As will be pointed out in Section 19, a discovery as prosaic as that of fractional indices of refraction indicates that a distinction so fundamental to human beings as that between heavy matter and empty space, may be reversed under certain familiar circumstances.

In the second place, Clerk Maxwell long ago pointed out the possibility of reversing an isolated system, even here on the earth, by means of his so-called "demons." He could not, to be sure, prove that a mechanism which would perform their function of discriminating between fast and slow moving molecules is a physical possibility, but, on the other hand, no one has succeeded in proving it to be a physical impossibility, except by assuming the second law itself, and thus begging the question. When we consider how some of our modern applications of

radio-waves discriminate between impulses, it does not appear so very improbable that in time a mechanism may be devised to perform the function of Maxwell's demons, or at least one of like import to thermodynamics. There is at any rate no proof to the contrary.

In the third place, if the radiation theory is sound, a mode of reversing the universe is available which would be impossible with a static ether. Not only would radiation of high enough frequency to reverse the annihilation of matter be presumably unavailable with a static ether, but the energy emitted from the suns of space could not be conserved in the universal ocean of radiation by a gradual conversion into the ethereal form, thus reversing the processes occurring in the stars. A dynamic ether, however, would supply the conditions for both these processes. Indeed, it would appear fairly plausible to infer that in the presence of matter, at least under the conditions prevailing in the stars, ethereal radiation is constantly being converted into light, heat and like forms of radiation, whereas in the absence of matter, these latter forms of radiation are slowly being reconverted into the ethereal form. Thus the universe is kept running by a sort of reversing fluorescence, a backward and forward change of frequency—including perhaps change from transverse to longitudinal radiation and *vice versa*—and so never runs down.* No proof that this is actually occurring can

*It is of some interest to note that Dingle, in speculating on the question raised in this section, suggests a solution similar, but less definite, than the one here proposed, and implying some form of radiation theory. As these various convergencies toward a radiation theory indicate at once the trend and the necessity of modern physics, it will be worth while to quote his surmises, even though they include conclusions about the bounds of space which lie beyond the realm of useful speculation. Thus he says:

"What becomes of the energy which is unceasingly radiated into space? If space is infinite, the problem does not exist: the radiation which is not absorbed by matter travels on to infinity. But if, as we

be presented, but the radiation theory renders it a physical possibility, and the facts discussed in Section 15 afford some affirmative evidence for it.

The radiation theory, therefore, provides a plausible alternative to the contention that the universe is running down, as well as a plausible explanation of why it has not already run down, for if it is dynamic in the manner assumed by that theory, the humanly detected processes of dissipation, both of matter and of energy, may, and probably do, set in operation compensating processes, which reverse the tendency of dissipation to bring about permanent equilibrium between the forces of the universe.

are now coming to believe, space is finite though boundless, and the heavens are actually 'rolled together as a scroll,' as Isaiah saw them, the ether must be gradually accumulating energy which, in some unknown form, is either transfused more or less uniformly throughout its whole extent or concentrated in solitary places. If the former alternative be true, it may be that, in the interiors of stars, circumstances exist which bring about a transformation of the ethereal energy from the unknown form into radiation again. We should then have a cycle of energy changes, from radiation into the unknown form and back again into radiation, with respect to which the material part of the Universe would act as the directing agency." (Dingle, H., *Modern Astrophysics,* p. 395.)

CHAPTER VI

THE EQUATIONS VERSUS THE ASSUMPTIONS OF RELATIVITY

In Section 6 will be found a quotation from Einstein to the effect that "The special theory of relativity has crystallised out from the Maxwell-Lorentz theory of electromagnetic phenomena." The radiation theory grows from that stem also, but its roots extend further back to the light-loading ideas of Sellmeier and Helmholtz, supplemented by the idea of discontinuous velocity of light due to Michelson and Morley. When these ideas are combined with the ideas that the ether consists of radiation and hence an ether drag is a radiation drag, and that matter consists of radiation also and hence is subject to Doppler-displacements, the whole puzzling series of so-called "relativity" phenomena begin to coalesce into a coherent and consistent whole, free from all paradox. Moreover, the radiation theory thus originating is a physical theory and not a purely mathematical structure like the theory of relativity. In fact, it keeps much closer to Lorentz's original interpretation of his equations than does the relativity theory, for when once Lorentz's static ether is replaced by a dynamic one, the real physical significance of the Lorentz transformation equations, which are also the fundamental equations of the special theory of relativity, begins to appear. They are revealed as the expression of the Doppler-displacements naturally to be expected in bodies emitting and encountering radiation moving with the speed of light.

Without repeating what has been said in Chapter V

about the causes of gravitation, inertia, variation of mass, etc., attention may be called to the fact that in every case they are physical causes of the character to which physicists have all along been in the habit of appealing to explain phenomena. The ethereal radiation postulated by the radiation theory is not "subjective," but objective, apparently differing from light only in frequency and wave-length; and the fluorescence, pressure, momentum and Doppler-displacements attributed to it in order to explain physical phenomena, are properties known to be possessed by light.

Now I venture the statement that the theory of relativity proposes no alternative causal explanation, recognized by reason, of the phenomena to which the Lorentz transformation equations, or those of the general theory of relativity, apply, and in support thereof direct attention to the following words of Mill:

"I premise, then, that when in the course of this inquiry I speak of the cause of any phenomenon, I do not mean a cause which is not itself a phenomenon; I make no research into the ultimate or ontological cause of anything. To adopt a distinction familiar in the writings of the Scotch metaphysicians, and especially of Reid, the causes with which I concern myself are not *efficient,* but *physical* causes. They are causes in that sense alone in which one physical fact is said to be the cause of another."[1]

The kind of cause to which Mill here refers as *physical* is the kind and the only kind known to science or recognized by logic. His canons of induction which embody the methods by which men recognize whether a phenomenon conforms to the definition of a cause or not, refer to no other kind. Without digressing unnecessarily into a

[1]Mill, J. S., *System of Logic,* book 3, chap. 5.

discussion of causation, I propose to inquire whether the causes postulated by the relativists are physical causes, or merely verbal appearances thereof.

Eddington tells us that the Lorentz contraction associated with the motion of a body "is not produced by any physical agency," yet it is the cause of, and hence explains the result of, the Michelson-Morley experiment. And Russell tells us that the increase of mass associated with the motion of a body "has no physical significance," yet it is the cause of, and explains the result of, the Kaufmann-Bucherer experiment. Now every physicist must admit that the results of these critical experiments are due to *some* cause. The cause assigned by Eddington and Russell, however, is, according to their own words, not a physical agency and is without physical significance. Can a thing with such characteristics be a physical cause? Evidently not. If a cause at all, it is not one recognized by any canon of induction known to science. It must be an "efficient" cause, whatever that may be. There are reasons to believe, indeed, that the "causes" of phenomena postulated by the relativists are mere unintelligibilities, which are able to pose as explanations by the power of suggestion contained in the words which claim to express them and the analogies which suggest the words. Let us, for example, consider such things as the "fourth dimension," and the "curvature of space-time," both of them often referred to by relativists. These things are admittedly not ordinary phenomena which we observe around us, like light and matter and motion in their many varieties. They are not things *observed* for which men *seek* an explanation. What office in science do they serve then? It must be as means of explaining things that *are* observed—means whereby men may *find* an explanation—since otherwise there

would be no reason why physicists should refer to, or be interested in, them. And this view of the matter is confirmed by the words of the relativists, often repeated. We are informed, for instance, that the phenomena observable when bodies are in very rapid motion depart from the laws of Newtonian mechanics *because* there are four dimensions in our world instead of three, as Newton supposed, time apparently being the fourth. And we are informed that the phenomena of gravitation and inertia observable about us, are thus observable *because* "space-time" has a "curvature," instead of being without one. Physicists in general are suspicious of such causal explanations as these. There appears to be something "off-color" about them. And logic bears them out in this judgment. Let us consider, for example, how consistent the relativists and non-Euclideans themselves are about this fourth dimension. Einstein has this to say about it:

"The non-mathematician is seized by a mysterious shuddering when he hears of 'four-dimensional' things, by a feeling not unlike that awakened by thoughts of the occult. And yet there is no more common-place statement than that the world in which we live is a four-dimensional space-time continuum. Space is a three-dimensional continuum."[2]

And Eddington is even more explicit in affirming that no fourth dimension of space has been newly discovered by the non-Euclideans or relativists:

"There is a strange delusion that the fourth dimension must be something wholly beyond the conception of the ordinary man, and that only the mathematician can be initiated into its mysteries. It is true that the mathematician has the advantage of understanding the technical

[2]Einstein, A., *Relativity*, p. 55.

machinery for solving the problems which may arise in studying the world of four dimensions; but as regards the conception of the four dimensions of the world his point of view is the same as that of anybody else. Is it supposed that by intense thought he throws himself into some state of trance in which he perceives some hitherto unsuspected direction stretching away at right angles to length, breadth and thickness? That would not be much use. The world of four dimensions, of which we are now speaking, is perfectly familiar to everybody. It is obvious to everyone—even to the mathematician—that the world of solid and permanent *objects* has three dimensions and no more; that objects are arranged in a threefold order, which for any particular individual may be analysed into right-and-left, backwards-and-forwards, up-and-down. But it is no less obvious to every one that the world of *events* is of four dimensions; that events are arranged in a fourfold order, which in the experience of any particular individual will be analysed into right-and-left, backwards-and-forwards, up-and-down, *sooner-and-later*. The subject of our study is external nature, which is a world of events, common to all observers but represented by them differently in their parochial frames of space and time; it is obvious to the most commonplace experience that this absolute world contains a fourfold order.*

"The news that the events around us form a world of four dimensions is as stale as the news that Queen Anne is dead. The reason why the relativist resurrects this ancient truism is because it is only in this undissected combination of four dimensions that the experiences of all observers meet."[3]

*"The relativity theory does not suggest that there is such a thing in nature as a four-dimensional *space*. The whole object of the recognition of the four-dimensional world is to eliminate the harassing frame of space."

So the mysterious "space-time" is only our familiar friends space *and* time with an unfamiliar spelling, and

[3]Eddington, A. S., *The Theory of Relativity and Its Influence on Scientific Thought,* The Romanes Lecture, 1922, pp. 15, 16.

space has only three dimensions after all. But compare these statements with the following from the distinguished mathematician Poincaré:

"Beings with minds like ours, and having the same senses as we, but without previous education, would receive from a suitably chosen external world impressions such that they would be led to construct a geometry other than that of Euclid and to localize the phenomena of that external world in a non-Euclidean space, or even in a space of four dimensions. . . .

"Nay more; with a little effort we likewise could do it. A person who should devote his existence to it might perhaps attain to a realization of the fourth dimension."[4]

Here we find that it is not the "world of events," or "the absolute world," or a "space-time continuum," but *space* itself, which has four dimensions. Yet Einstein and Eddington assure us it has only three. Moreover we discover that the "common-place statement," the "ancient truism" which is "obvious to everyone" and the news of which "is as stale as the news that Queen Anne is dead" expresses something so difficult to grasp that "a person who should devote his existence to it might perhaps attain to a realization" of it. What are we to make of such a discrepancy as this? Is there some profound misunderstanding here? Perhaps so. At least it has the profundity of any other verbal misunderstanding—a kind more difficult to elude than very profound non-verbal ones. Calling time a "dimension" instead of a "variable," as was formerly the practice, has simply enabled Poincaré to "discover" that it is a direction in space, because, of course, if it is a "dimension" it must be. The other three dimensions, length, breadth and thickness are directions in space.

[4]Poincaré, H., *The Foundations of Science*, p. 66.

But time is a dimension also. Three dimensions plus one dimension make four dimensions. Therefore, time is a fourth dimension. Q. E. D.

Thus the non-Euclideans have changed the thing by changing its name. It is a typical verbal mix-up only too familiar to those who have delved into the vagaries of metaphysics. It differs in no essential respect from the one noted in Section 6, which enabled Eddington to discover a peculiar kind of contraction that is produced by a physical agency which does not produce it. Eddington, indeed, appears much confused as to where his fourth dimension belongs in the scheme of things. In the quotation just given he locates it in the world. It is the thing familiar to all of us as time, and he is disposed to joke at the non-mathematician's confusion about it, but elsewhere he says that it is "necessary to give up the reality of the everyday world of three dimensions,"[5] thus ignoring his own statement that this "everyday world" has four, and hence there can be no such "world of three dimensions" to give up. Yet again he informs us that "So far as three-dimensional space is concerned the applicability of Euclidean geometry is very closely confirmed by experiment,"[6] which certainly implies there is such a thing as "space" of other than three dimensions. Otherwise, why refer to the "three-dimensional" kind? Has he forgotten that space has only three dimensions, thus disregarding his own warning not to confound "space" with "the world"? Surely his language would arouse such a suspicion, and one rather completely confirmed when turning to another of his works we find him informing us that "until recently the practical man was never confronted with problems of non-Euclidean space."[7] Here then is news

[5]*Space Time and Gravitation*, p. 182. [6]*Ibid.*, p. 47.
[7]*The Mathematical Theory of Relativity*, p. 4.

about *space* more recent than Queen Anne's death. Were there opportunity to go into the matter we could indefinitely multiply these inconsistencies of the relativists, Einstein by no means being exempt. However, this much must suffice for this particular muddle.

If we follow up the so-called "curvature of space-time" we find a similar mix-up. In fact, the idea of curvature in space-time is a variation of that of the fourth dimension—*née* variable—if we care to classify such things under the category of "ideas" at all. They are at least states of mind associated with particular words. It is derived from the same analogy at least. We are first invited to consider what would be observable to beings whose capacity to observe is confined to a space of two dimensions if they found themselves dwelling in a space which "really" has three dimensions. They would encounter anomalies which a three-dimensional observer, like ourselves, could easily explain by means of the extra dimension which we are qualified to observe. By analogy then we can imagine a four-dimensional observer who could easily explain anomalies perceived by us three-dimensioners. Now anomalies are revealed by various experiments and observations, notably the experiments of Michelson-Morley and Kaufmann-Bucherer, and the observation of the motion of Mercury's perihelion. Ergo, they may be explained by a fourth dimension, and the curvature of the resulting mixture called space-time caused by matter. It is obvious that by this kind of analogy we can discover the existence of five, six, ten or *n*-dimensions in "space" or the "world." Indeed Eddington informs us that "Our four-dimensional space-time may be regarded as a closed surface in a five-dimensional continuum."[8] And all these dimensions will

[8] *Report on the Relativity Theory of Gravitation*, p. 84.

be equally intelligible and endowable not only with "curvatures," but other characteristics, including perhaps colors and odors. But can we trust these mathematical fictions to give us real explanations on which we can depend? If so, why explain things by a fourth dimension? Why not a fortieth?

To illustrate the illusory nature of relativity explanations, let us turn to a few statements about space-time and its curvature to be found in Eddington's *Nature of the Physical World.* Thus we are told that: "The term non-Euclidean geometry refers to a more profound change, viz. that involved in the curvature of space and time by which we now represent the phenomenon of gravitation" (page 136). From which we receive confirmation of the statement already noted (see page 173) that the mysterious "space-time" merely means space *and* time, which means not only that space is curved, but *time* is "curved" also! Yet in another place we learn that "This space-time may be materialised as the ether,"[9] which is certainly strange news about space *and* time. We also learn that their, or its, "curvature" represents gravitation, and if profundity is proportional to unintelligibility, as is popularly assumed, we must agree with Eddington that a profound change has come over space and time since they became curved, as profound as if they had become intoxicated. Perhaps, indeed, in this latter suggestion we have a clue to the cause of the curvature. A little later another announcement is made as follows: "We do not ask how mass gets a grip on space-time and causes the curvature which our theory postulates . . . the mass *is* the curvature" (page 156). Here is another discovery, apparently made by noticing resemblances in the form of equations and drawing

[9] *Ibid.*, p. 79.

profound (= unintelligible) analogies from them. Our greatest illumination, however, is received from Chapter 8, where we find the following: "Consider a portion of space-time, say Great Britain between 1915 and 1925" (page 180). Here we have a *concrete example* of a portion of space-time, from which former statements about that admirable magnitude enable us to conclude that the curvature of Great Britain between 1915 and 1925 is mass, or a portion of mass, and represents gravitation, though we are not informed what portion of mass it is, or what particular gravitation it represents. Perhaps it is the mass and gravitation of Great Britain during those years that is being referred to, and we wonder whether the curvature would be different if the interval were between 1615 and 1625, or between 1215 and 2425. But we are left in the dark about such matters. This statement also requires, according to Eddington's statement in his report on gravitation, that Great Britain between 1915 and 1925 may be materialized as the ether or a portion of it. No wonder relativists have difficulty in crediting the existence of an ether if it is the materialization of such a thing. Reducing "space-time" and its "curvature" to the concrete thus reveals their true character as mere meaningless sounds or letter-combinations, and constrains us to repeat a remark which we find Eddington making, to the effect that "It does not seem a profitable procedure to make odd noises on the off-chance that posterity will find a significance to attribute to them" (page 21). The fact is these analogies of the relativists should be taken for what they are, namely, analogies. They are of substantially the same metaphorical character as the explanations of phenomena in ancient days by means of "exhalations," "animal spirits" and "vapors," based on similar analogies and producing

in the human mind the same symptom as those produced by the non-Euclidean explanations, namely, elimination of a feeling of doubt. Thus the phenomena of thunderstorms were due to "exhalations" of nature or God, analogous no doubt to the coughing of a human being, and when such "explanations" were offered to laymen by the proper authority their doubt about the cause of the storm was dispelled. Indeed, suggestive analogies, especially if suggestively named, are easily mistaken for physical causes, and there is reason to believe that "fourth dimension" and "curved space" and other analogy-bred terms are of this character. They are metaphors like "green old age" or "humble cot" and based on like analogies. No doubt attaches to the analogies—they are plain enough. The doubt attaches to their explanatory power. The only kinds of curvature of space-time that I have found relativists referring to are spherical, elliptical and cylindrical, but why should there not be other kinds? Why indeed, should there not be space-time shaped something like the north-west quadrant of an emotion? If a person "should devote his existence to it he might perhaps attain to a realization" of such a thing, and thus be enabled to explain many matters not otherwise explainable. So far as I am personally concerned, a "green-colored age," a "cottage which feels humility," and the "northwestwardness of an emotion" are terms as intelligible as "the cylindricalness of space-time." And I find I am not alone in this incapacity to grasp the meaning of the relativist explanations. I have talked with many trained physicists, and have yet to find one who claimed to understand these explanations. On the other hand, I have talked with persons not physicists who found them easy to understand. These understanding persons are to be found especially

among the mystic-minded, who discover their own foggy impressions of the universe confirmed. Many metaphysicians, indeed, not only find the ideas of relativity easy to understand, but an old story. Thus Carr says, referring to Einstein's discovery:

> "To the metaphysician there is nothing subversive or revolutionary in the new principle, it is practically identical with principles which have, time and again, been formulated in philosophy, ancient and modern, but to the man of science it seems like a sudden upheaval of the foundations on which the whole stupendous structure of modern science has been reared."[10]

Thus it is not the physicists, it is the metaphysicians, who most easily understand Einstein. His "explanations" are the kind they are accustomed to. They have known all along that space-time had a curvature. About the only others who understand him are a few mathematicians, who apparently mean by "understand," a capacity to handle the mathematics of his theory and obtain results from it. But capacity to handle symbols is one thing, and understanding a non-understandable, like a red odor, an onion-flavored sound, an octagonal shaped time, or a cylindrically curved space-time, is another.

No doubt these analogies are suggestive and hence useful, but it is a mistake to take them too seriously. Flint expresses the sane view of these allegorical geometries of n-dimensions when he says:

> "We should . . . regard the hypothetical n-dimensional space as a mere convenience, we should not give it a physical significance; the phenomenon is still one of three dimensions."[11]

[10]Carr, H. W., *The General Principle of Relativity*, pp. 3, 4.
[11]Flint, H. T., *Wave Mechanics*, p. 24.

And later he makes it entirely clear, as DeBroglie does on page 189 in the next chapter, that a non-Euclidean "dimension" is simply a misleading synonym for a variable or degree of freedom, thus:

"In making the extension contemplated in wave mechanics we have to take over our geometrical ideas of three dimensions and apply them to *n*-dimensions. The surfaces corresponding to systems are *n*-dimensional, where *n* is equal to the number of degrees of freedom of the system. This we must regard as merely a convenient mode of expression, and when we speak of surfaces and waves in *n*-dimensions we speak by analogy."[12]

Carmichael also realizes that a non-Euclidean "dimension" arises from a mere shift in the ordinary meaning of the word, for he says:

"I have no intention of asserting that time is a fourth dimension of space in the sense in which we ordinarily employ the word 'dimension'; such a statement would have no meaning."[13]

From these various evidences among others I conclude that the alleged "causes" by which relativists "explain" physical phenomena are not physical causes as defined by Mill and familiar to scientists, but are unintelligibilities which are successful in posing as such in virtue of the associations suggested by the analogies to which the words direct attention. And it is the failure to distinguish between genuine explanations and these verbal substitutes that leads relativists and other metaphysicians into the contradictions in which we find them. That such substitutes are able to dispel some persons' feelings of doubt about the

[12]*Ibid.*, p. 26.
[13]Carmichael, R. D., *The Theory of Relativity*, p. 48.

cause of gravitation, increase of mass with motion, etc., etc., proves nothing. For though explanations are good dispellers of doubt, all dispellers of doubt are not explanations. The relativity theory, therefore, suggests no physical cause of the phenomena to be explained, and thus proposes no alternative to the explanations proposed by the radiation theory, which are genuine, if hypothetical, physical causes.

But the confusion about space, time, fourth dimension, etc., etc., traceable to these verbal causes and based on verbal assumptions, has led relativists, or most relativists, into a number of conclusions expressible in material propositions which are apparently untrue, and it is to some of these assumptions that I now wish to call attention. Such a statement as "Time and space are relative" expresses a verbal assumption only, since it is merely a contraction of the truism that "Relative time and space are relative." But the contracted form of statement conceals the truism, and leads men to think that it expresses a theory, open to debate, and hence the result of a discovery, and this in turn leads them to make real assumptions which bring them into collision with the facts. Thus if Einstein by his "interpretation" of the Lorentz transformation equations is able to "discover" that their conformity to fact is due to characteristics of time and space not previously suspected, the need for Lorentz's "interpretation" that this conformity is due to the influence of an ether on bodies moving through it, becomes superfluous. There is doubt about the existence of an ether, but there is no doubt about the existence of space and time. Hence why explain things by an ether when they can be more simply and certainly explained by newly discovered characteristics of things about the existence of which there is no doubt?

By such reasoning relativists abolish the ether, and if there is no ether and hence no unique "frame of reference" in the universe, there can, of course, be no motion or acceleration relative to it. This in turn leads to the assumption—a real, not a verbal, one—that the motion and acceleration of material bodies is relative exclusively to other material bodies. Furthermore, the fact that in the Lorentz transformation $+t$ on one frame of reference may become o or $-t$ on another, leads mathematicians wedded to the relativist interpretation of these symbols to the conclusion that time can stand still, or even move backward. Events in the present, therefore, can become the causes of events in the past, thus refuting the law of causation which affirms that events in the present can only causally affect events in the future. And this assumption that the law of causation has been modified or rendered obsolete by Einstein's discoveries about space and time is another real one, expressible in a material proposition. There are various other real assumptions, also, such as that the velocity of light is the limiting velocity in the universe, but I wish particularly to direct attention to the following three, because they are the most important to emphasize:

(1) The motion of a material body is relative exclusively to other material bodies.

(2) The acceleration of a material body is relative exclusively to other material bodies.

(3) The law of causation, as understood by Mill and men of science generally previous to the theory of relativity, is untrue or inaccurate.

We shall examine these and other assumptions, and some of their consequences presently. Our immediate task is to contrast these *assumptions* of relativity with

the *equations* of relativity, and point out that the two have no necessary connection with one another, and hence that the verification of the equations constitutes no necessary verification of the assumptions, and the refutation of the assumptions constitutes no refutation of the equations. It is important to point this out because *the evidence indicates that while the facts confirm the equations they refute the assumptions.*

That the truth of an equation does not necessarily imply the truth of an assumption about external nature is a fact which can be readily demonstrated. Thus the interpretations of the Lorentz transformation equations suggested by Lorentz and Einstein respectively *both* agree with the equations, despite the fact that the former assumes an ether and the latter does not. That is what Einstein means when he says, as he constantly does, that there is no opposition between the two theories. Hence the equations do not confirm one and refute the other, but confirm both, so far as it is possible for an equation to confirm a physical hypothesis. Neither do any other equations choose between them. The three assumptions above named, therefore, are neither proved nor disproved by the equations of relativity, special or general. Thus to prove that the equations agree with the facts proves nothing about the assumptions, any more than in the parallel case of the *d*- and *l*-effects (pages 26, 27). *Yet no other method of proving their assumptions is even suggested by the relativists.* He who has grasped the nature of a dimensional explanation will not fail to see the futility of such a procedure.

The fact is that the policy of using one name for two meanings has caused the relativists to continually confound Einsteinian magnitudes with Newtonian ones, and these assumptions are one result of that policy. They are

not consequences which follow by definition from the equations of relativity. If they were it would be futile to debate them. They are hypotheses, implying Newtonian magnitudes, superimposed upon the equations, and hence open to debate, and the applications thereof made by the relativists to ordinary, humanly observable, examples of motion, acceleration and causation, make it plain that they so understand them. The equations *per se* say nothing about the existence or non-existence of unique frames of reference, and hence nothing about absolute motion or acceleration. Neither have they anything to say about the law of causation or the velocity of the physical agent light. As Eddington points out (page 11) they deal with ideal magnitudes whose identification with humanly observable ones is open to question. Thus the equations and assumptions of relativity do not stand or fall together, as popularly supposed. They are quite independent of one another. The issue of the truth of the equations, therefore, must be kept entirely separate from that of the truth of the assumptions. There is apparently no occasion to question the substantial truth of the equations. In their curious dimensional way they evidently express a truth of cosmic proportions. But they no more prove the assumptions of relativity than the fact-predicting equation on page 26 proves the assumption that the velocity of light is infinite. In the chapter following we shall question the assumptions and some of their consequences for the purpose of showing that those who support them contradict not only observed facts and confirmed theories, but contradict one another, and even contradict themselves.

CHAPTER VII

QUESTIONING THE RELATIVITY ASSUMPTIONS

FOLLOWING up the distinction made in the last chapter, we shall in this one address some pertinent questions to the relativity assumptions, as in Chapter V we addressed some to the radiation theory. In the case of the latter there was no occasion to distinguish between the equations and the assumptions, since the quantitative statement of the theory has not yet been independently worked out. In the case of the relativity theory, however, a distinction is necessary in order to avoid confounding two issues. To question the relativity "theory" would be likely to lead to confusion, since that word, as used by the relativists, applies both to the equations and the assumptions which have been superimposed upon them, the latter constituting the relativist "interpretation." These assumptions comprise the only part of the relativity theory that strictly corresponds to the radiation theory.

The chief difficulties of relativity are connected with the two assumptions first named on page 183. The third one is a pure speculation, which can appeal to no facts which even appear to confirm it. No influence on the past by events in the present has ever been observed or reasonably inferred. The radiation theory acquiesces in none of these assumptions, but it would agree with the first two if the word "exclusively" were omitted. In short, it does not deny that the motion and acceleration of material bodies are relative to one another. What it denies

is that they are relative to nothing else. Indeed it affirms that the motion or acceleration of two material bodies relative to one another always involves the motion or acceleration of one or both of them relative to something else; that something else being a field of radiation which, for convenience, is called the ether. If we please we may call this latter motion absolute—and motion relative to an ether is generally so called by the relativists—but the sound of the name should not blind us to the fact that absolute motion or acceleration is just as much relative as that of one material body relative to another. Moreover, if the radiation theory is sound, this absolute motion has profound physical significance. We shall find, in fact, that the denial by the relativists of this unique ethereal frame of reference is a rock on which the philosophy of relativity founders. And no less eminent a proponent of relativity than Eddington coincides with this conclusion (see page 278).

The fact is, the relativists, in claiming that the motion and acceleration of bodies are relative exclusively to those of other bodies, are victims of what Huxley calls the "nothing but" habit of mind so tempting to the speculator. They are over-simplifying nature, and attempting to reduce mechanics, and even physics itself, to a curious light-limited geometry, as the following citations will illustrate:

"Physics is, as it were, a Euclidean geometry of four dimensions."[1]

"The world is a (3 + 1) dimensional metrical manifold; all physical field-phenomena are expressions of the metrics of the world. . . .

[1]Einstein, A., "A Brief Outline of the Development of the Theory of Relativity," *Nature,* vol. 106, p. 783.

"Descartes' dream of a purely geometrical physics seems to be attaining fulfilment in a manner of which he could certainly have had no presentiment."[2]

"We found that it was impossible to confine geometry to space alone, and we had to let it expand a little. It has expanded with a vengeance and taken a big slice out of mechanics. There is no stopping it, and bit by bit geometry has now swallowed up the whole of mechanics. It has also made some tentative nibbles at electromagnetism. An ideal shines in front of us, far ahead perhaps but irresistible, that the whole of our knowledge of the physical world may be unified into a single science which will perhaps be expressed in terms of geometrical or quasi-geometrical conceptions."[3]

It would seem that this ideal of reducing electromagnetism as well as mechanics to "geometry," instead of shining far off in front of us, had already been achieved by M. Kaluza some years before Eddington's book was published. It will be found explained in *Sitzungsber. d. Berl. Akad.* (1921), p. 966. At least this is DeBroglie's claim, for speaking of this solution of the problem he tells us:

"In order to perfect Einstein's work and reduce electromagnetic force to geometrical quantities, M. Kaluza has developed a bold but very elegant theory: the theory of relativity in five dimensions."[4]

The method of realizing this ideal was the same as that used by Einstein in reducing mechanics to geometry—a very simple one. It is only necessary to change the name "variable" or "degree of freedom" to "dimension," and the deed is done. Thus DeBroglie explains the process:

[2]Weyl, H., *Space—Time—Matter,* pp. 283, 284.
[3]Eddington, A. S., *The Nature of the Physical World,* p. 136.
[4]DeBroglie, L., *Selected Papers on Wave Mechanics,* p. 102.

"**Five-dimensional Relativity.**—Let us imagine with M. Kaluza that, in order to represent the series of events in the Universe, it is necessary to employ a manifold of five dimensions; that is, a fifth dimension, corresponding to a fifth variable, x°, is to be added to space-time. The variations of this fifth variable are quite beyond our senses, so that two points of the Universe corresponding to the same values of the four variables of space-time but to different values of the variable x° are indistinguishable. We are, as it were, shut up in our space-time manifold of four dimensions, and we perceive only the projections on this space-time of points in the Universe of five dimensions."[5]

The results of this name-changing process are satisfactory it seems, and physics is now, according to De-Broglie, entirely reduced to geometry. For, voicing the general view of physicists, he tells us that:

"In the present state of our knowledge, it appears that all the forces which we know from experience to exist are reducible to two types only: gravitational forces and electromagnetic forces."[6]

And then proceeds to say of Kaluza's achievement:

"By means of a principle of variation, Einstein's law of gravitation and at the same time Maxwell's equations can be deduced from the conception of the Universe of five dimensions. . . . *'In the five-dimensional Universe, the world-line of every material particle is a geodesic.'* "[7]

All of which is well worthy the attention of physicists, and will cause no confusion if it is understood that "dimension" simply means "variable" and implies nothing geometrical beyond three dimensions. Indeed Eddington

[5] *Ibid.*, p. 104. [6] *Ibid.*, pp. 101, 102. [7] *Ibid.*, p. 106.

himself admits that his "irresistible" ideal is merely verbal and that there is nothing geometrical about non-Euclidean mechanics but the vocabulary, for he says:

> "Mechanics in becoming geometry remains none the less mechanics. The partition between mechanics and geometry has broken down and the nature of each of them has diffused through the whole. The apparent supremacy of geometry is really due to the fact that it possesses the richer and more adaptable vocabulary."[8]

To thus reduce all things to "nothing but" geometry is, naturally, alluring to the speculator. All persons of a philosophical turn of mind seek unity, but they must beware of finding unity where there is no unity, at least of the kind which their assumptions require. The course of nature cannot be expressed by a science as static as geometry. In this chapter we shall have occasion to show plainly, especially in Sections 18 and 23, that the relativists have been misled by their eagerness to find a geometrical unity in nature of a kind that does not exist there.

To continue our comparison of the relativity and radiation assumptions, we may, after the interruption afforded by the preceding chapter, proceed to question the relativity assumptions in a series of sections, numbered consecutively with those of Chapter V. The questions follow:

Section 17. Does the ether exist?

Consultation of the works of the relativists appears to leave the answer to this question in some doubt. Most interpreters of the theory assert that it involves the non-existence of the ether. Others assert that it does not. Still

[8]Eddington, A. S., *The Nature of the Physical World,* p. 137.

others, including Einstein, appear to make both assertions.

Bridgman informs us that:

"There is nowhere any physical evidence for the inclusion of a third element (the ether)."[9]

Weyl and Stewart are even more emphatic about the non-existence of the ether, and cite Einstein as their authority:

"The only reasonable answer that was given to the question as to why a translation in the ether cannot be distinguished from rest was that of Einstein, namely, that *there is no ether!*"[10]

"As has been shown by Einstein and others, the first postulate of relativity leads to the rejection of this concept of the ether."[11]

Sommerfeld also, by implication, asserts the non-existence of the ether as follows:

"Electrodynamics, in giving up *absolute space* (ether), is simultaneously compelled to give up *the idea of absolute time.*"[12]

But on an earlier page he says:

"In addition to the atom which excites the radiation, we suppose an 'ether' to exist, which transmits the radiation. Nowadays we like to avoid speaking of the ether, since the theory of relativity has deprived it of its material existence in the older sense."[13]

It appears that Sommerfeld is in the habit of doing

[9]Bridgman, P. W., *The Logic of Modern Physics,* p. 166.
[10]Weyl, H., *Space—Time—Matter,* p. 172.
[11]Stewart, O. M., "The Second Postulate of Relativity and the Electromagnetic Emission Theory of Light," *Physical Review,* vol. 32, p. 419.
[12]Sommerfeld, A., *Atomic Structure and Spectral Lines,* p. 457.
[13]*Ibid.,* p. 215.

what he likes to avoid doing, for he follows up this assertion and denial of the ether by another apology, as follows:

> "Before proceeding further, we shall interpose, as we have already done on page 215, a few remarks to excuse the use of the word 'ether.' From the point of view of the theory of relativity we must deny the reality of a universal ether transmitting light."[14]

Moreover, throughout the whole exposition in which these apologies occur, he assumes the existence of the ether, and his conclusions would be of no value, if indeed of any meaning, without it.

Jeans also, though lacking the complete confidence of the foregoing, informs us that:

> "The time has now clearly come when . . . the electrodynamic ether must be either amended or abandoned, and the indications are strong that the less drastic course will not suffice."[15]

Bridgman is more confident than Jeans about the nonexistence of the electrodynamic ether and the "fields" attributed to it—the same ether of course to which gravitational fields are attributed—for he says:

> "I believe that a critical examination will show that the ascription of physical reality to the electric field is entirely without justification. . . .
>
> "It is sufficient to mention the fate of the attempt of Faraday and Maxwell to ascribe a stress like that of ordinary matter to the ether, which failed because, among other reasons, nothing can exist in the ether analogous to the *strain* of ordinary matter, to indicate the unfruit-

[14] *Ibid.*, p. 258.

[15] Jeans, J. H., "The General Physical Theory of Relativity," *Nature*, vol. 106, p. 792.

fulness of the idea of physical reality. It seems to me that any pragmatic justification in postulating reality for the electric field has now been exhausted."[16]

And Tolman, agreeing with Stewart, already quoted, says:

"The first postulate of relativity practically denies the existence of any stationary ether through which the earth for instance might be moving."[17]

Perhaps as unqualified a repudiation of the ether theory as can be found anywhere is the following from Lewis:

"Often in our more carefully cultivated gardens of thought some rank weed grows with such vigor as to stunt the growth of the neighboring useful vegetables. So the scientific literature of the nineteenth century was overgrown with a discussion of the ether, its stresses and its strains, its density, its movement with the earth or through the earth. A mechanism that we designed to be a servant had become our master; until now that we are suddenly freed from this obsession we feel as if awakened from a hideous nightmare."[18]

The chasm between these relativists and the non-relativists may be suggested by comparing such statements as the foregoing with the following from an authority no less distinguished than Thomson:

"All mass is mass of the ether, all momentum, momentum of the ether, and all kinetic energy, kinetic energy of the ether."[19]

But the chasm is not one separating relativists and non-relativists, but divides the relativists themselves, as indi-

[16]Bridgman, P. W., *The Logic of Modern Physics*, pp. 57, 58.
[17]Tolman, R. C., "The Second Postulate of Relativity," *Physical Review*, vol. 31, p. 28.
[18]Lewis, G. N., *The Anatomy of Science*, p. 75.
[19]Thomson, J. J., *Electricity and Matter*, p. 51.

cated by the following expressions from well-known expounders and defenders of relativity:

"It is often objected that relativity purports to disprove the existence of the ether, and that without the ether phenomena such as the propagation of light are inconceivable. It is not certain that relativity does do this."[20]

"The most formidable objection to this relativist view of the world is the ether difficulty. . . . Some would cut the knot by denying the ether altogether. We do not consider that desirable, or so far as we can see, possible."[21]

"We need an ether. The physical world is not to be analysed into isolated particles of matter or electricity with featureless interspace. We have to attribute as much character to the interspace as to the particles. . . . We postulate ether to bear the characters of the interspace as we postulate matter or electricity to bear the characters of the particles. . . .

"The ether itself is as much to the fore as ever it was, in our scheme of the world."[22]

Notice also in this connection what Einstein himself has to say about the physical reality of a "medium" and its "fields":

" 'If we pick up a stone and then let it go, why does it fall to the ground?' The usual answer to this question is: 'Because it is attracted by the earth.' Modern physics formulates the answer rather differently for the following reason. As a result of the more careful study of electromagnetic phenomena, we have come to regard action at a distance as a process impossible without the intervention of some intermediary medium. If, for instance, a magnet attracts a piece of iron, we cannot be content to

[20]Jeffery, G. B., *Relativity for Physics Students,* p. 30.
[21]Eddington, A. S., *Space Time and Gravitation,* pp. 38, 39.
[22]Eddington, A. S., *The Nature of the Physical World,* pp. 31, 32.

regard this as meaning that the magnet acts directly on the iron through the intermediate empty space, but we are constrained to imagine—after the manner of Faraday—that the magnet always calls into being something physically real in the space around it, that something being what we call a 'magnetic field.' In its turn this magnetic field operates on the piece of iron, so that the latter strives to move towards the magnet. We shall not discuss here the justification for this incidental conception, which is indeed a somewhat arbitrary one. We shall only mention that with its aid electromagnetic phenomena can be theoretically represented much more satisfactorily than without it, and this applies particularly to the transmission of electromagnetic waves. The effects of gravitation also are regarded in an analogous manner."[23]

Does this passage deny the existence of an ether? If so, what is the "intermediary medium" which he asserts is concerned in reactions between bodies separated by a distance, and particularly with "the transmission of electromagnetic waves"?* Is it something different from an ethereal medium? And how about the fields, magnetic and gravitational, presumably in this medium, which he asserts are "physically real"? Is he expressing by this assertion his judgment that they are unreal? Is he agreeing with Bridgman in the passage above quoted, that "the ascription of physical reality to the electric field is en-

[23]Einstein, A., *Relativity*, pp. 63, 64.

*Note also what Einstein says in the quotations in Section 1, where he also makes reference to this same "intermediary medium," and certainly appears to express agreement with the "Faraday-Maxwell interpretation" which, be it recalled, was an interpretation by means of an ether just as explicit as that of Lorentz, with which, in another place, Einstein disagrees. For in *Relativity*, page 53, referring to Lorentz's "contraction" theory, which assumes an ether, he remarks: "According to this [relativity] theory there is no such thing as a 'specially favoured' (unique) co-ordinate system to occasion the introduction of the ether idea." Yet how does the "ether idea" which he rejects differ from the "intermediary medium" idea which he accepts? Is it not one of those "word-splitting" differences referred to by Eddington on page 279, to which the relativists are so partial?

tirely without justification"? The relativists claim that Einstein denies the reality of the ether or any equivalent of it. Perhaps he does, but if so, he seems to select language to express his denial that other physicists would select to express their affirmation.

These are fair samples of the uncertainty about the existence or non-existence of the ether and its fields prevailing among relativists. The preponderance of opinion among them is, however, that the ether does not exist. A little later, nevertheless (Section 24), we shall see that they are forced by the facts of physics to bring the ether back into existence in a very definite manner, albeit under another name.

In the discussion of this question there is less verbal confusion among relativists than is commonly the case, but the explanation of the disposition on their part to deny the existence of the ether will become apparent in the section following. It is in fact a practical necessity for them to deny it if they maintain the doctrine of the relativity of motion and acceleration in the form in which they do, at least explicitly, maintain it.

Let us next compare the two theories with respect to the issue raised by this doctrine.

Section 18. Is the motion of material bodies relative exclusively to other material bodies?

To this question the theory of relativity returns a less uncertain answer than to the preceding one. Its answer is explicitly yes. Carmichael, for instance, tells us that:

> "The only motion of which we can have any knowledge is the motion of one material body or system of bodies relative to another."[24]

[24]Carmichael, R. D., *The Theory of Relativity*, p. 16.

Eddington confirms him thus:

"Motion with respect to ether or to any universally significant frame would be called absolute.

"No ethereal frame has been found. We can only discover motion relative to the material landmarks scattered casually about the world; motion with respect to the universal ocean of ether eludes us."[25]

Schlick expresses the same idea in terms of a mutuality of motion confined to that between material bodies:

"All phenomena . . . depend only on the *mutual* position and motion of bodies."[26]

And Tolman presents the case as follows:

"It [the Einstein theory] states that there is nothing out in space in the nature of an ether or of a fixed set of coordinates with regard to which motion can be measured, that there is no such thing as absolute motion, and that all we can speak of is the relative motion of one body with respect to another."[27]

Yet Eddington, as shown in the last section, maintains that there is an ether, and Einstein speaks of magnetic and gravitational fields as "physically real in . . . space." If these eminent relativists are correct, then, there must be something in space to which the motion of a material body may be relative beside another material body. Such inconsistencies, however, are the least of the troubles which beset the relativity assumptions. Let us turn to a couple of conflicts in which the assumption considered in this section involves the theory. The first is a conflict with another theory; the second a conflict with facts.

[25]Eddington, A. S., *The Nature of the Physical World*, p. 30.
[26]Schlick, M., *Space and Time in Contemporary Physics*, p. 44.
[27]Tolman, R. C., *The Theory of the Relativity of Motion*, p. 18.

Before considering these, however, it should be noted that, despite the expressions above quoted, the relativists do not intend to deny the possibility of material motion relative to various wave-trains. They would not deny that sound, water and light waves could move past material bodies. What they deny is that waves traversing "empty" space move in a medium in any such way as sound or water waves do. Hence, to meet the facts, they have devised a dimensional disguise for the displacements of radiational waves which they have not devised for those of other kinds of waves. Thus radiation is placed in a class by itself, so far as its mode of propagation is concerned. Let us now proceed to the first conflict.

Assume two observers, *A* and *B*, each provided with a source of monochromatic light of frequency *N*, and a sufficiently sensitive spectroscope, to be situated at two stations on the earth's surface (assumed at rest in the ether) separated from each other by any suitable distance. Assume each to observe by means of his spectroscope the light emitted from the source situated at the station of the other. Assume now that *A* remains at rest relative to the earth, while *B* moves from his station toward *A* at a velocity *v* sufficient to cause an observable shift in both spectroscopes due to the resulting Doppler effect. The velocity of *A* relative to *B* will then be equal to the velocity of *B* relative to *A*, both velocities being *v*. But according to the undulatory theory of light, as expounded by Wood, who is in agreement with all classical physicists—

"The Doppler effect is . . . greater for the case of a moving source than for a moving observer. . . .

"The number of waves of frequency *N*, coming from a fixed source, which in one second pass an observer mov-

ing towards the source with a velocity v, is . . . $\frac{V+v}{\lambda}$, in which $V =$ velocity of light [and $\lambda =$ the wave-length].
"If, however, the observer is fixed, and the source moves with a velocity v, . . . the number of waves which pass the observer per second is . . . $\frac{V}{V-v}N$."[28]

The first formula, therefore, would provide the measure of the shift of wave-length (and hence of relative motion) as observed in *B's* spectroscope, whereas the second formula would provide the measure of the shift (and relative motion) as observed in *A's*, and the amount of the shift would be different in the two cases.* This inference follows from the undulatory theory. The relativity theory, however, requires that *A's* motion as inferred from observations, by means of light, at *B*, must be the same as *B's* motion as inferred from observations made by the same means at *A*. Tolman expresses this as follows:

"The first postulate of relativity adds [to the principle that the velocity of light is not changed by motion of its source] the idea that a motion of the source of light towards the observer is identical with a motion of the observer towards the source."[29]

The identity referred to in this passage must be an identity of effects in general (assuming sufficiently sen-

[28]Wood, R. W., *Physical Optics*, pp. 26, 27.

*There is a special case in which *A* and *B* would not observe different displacements, namely, when both are moving at the same velocity in the line of sight relative to the ether. It is only in this special case that the predictions of the undulatory theory and the relativity theory coincide.

[29]Tolman, R. C., "The Second Postulate of Relativity," *Physical Review*, vol. 31, p. 28.

sitive instruments), since it needs no postulate of relativity to reveal the identity of the relative velocities. Thus far it has not been found possible to test the divergent predictions of the two theories by experiment, though the effect predicted by the corresponding wave theory of sound has been verified. That is, the movement of the source produces a Doppler effect different from that produced by the movement of the observer. As Wood shows, however, the same difference follows by inference from the undulatory theory of light. But if an inevitable inference from the undulatory theory of light requires that a certain statement shall be true, whereas an equally inevitable inference from the relativity theory requires that the same statement shall be untrue, then the undulatory theory* and the relativity theory must be incompatible with each other, and one or the other must be false. Physicists, therefore, seem called upon to judge their relative probability. Judging from the sum of the available evidence, which, at present, appears the more probable? Without pausing to express our own judgment, which in any event would not be of any particular pertinence, we shall leave the answer to this question to the judgment of physicists.

In the foregoing instance the relativity theory is found to be in conflict only with another *theory,* but in the second case, to which we may now turn, it is in conflict with certain observed *facts* which appear to constitute a crucial refutation of the assumption relating to relative motion maintained by the relativists. The facts referred to relate to the Doppler effect, as in the conflict just discussed, and to realize their force it will be useful to present the con-

*The quantum theory would be in no disagreement with the undulatory theory on this issue.

trasted "interpretations" of this effect by the classical and relativist physicists respectively. The following account by Dingle states very well the opposition between them:

"When a source of radiation and an observer are either approaching or receding from one another, theory requires that the wave-length of the radiation, as measured by the observer, shall be slightly different from what it is when the relative motion does not exist. This is known as the Doppler principle. It can be, and has been, verified experimentally for the aerial waves which constitute sound. It is a familiar experience that an engine whistle appears to change its note abruptly when the engine passes a listener standing on the station platform. . . . For light waves, however, a proof quite so direct as this is not yet within the bounds of possibility. Light moves so exceedingly quickly compared with the relative speeds experimentally attainable, that the effect would be immeasurably small. Further, when we are dealing with ethereal waves, the theoretical aspect of the matter is by no means so simple as it is with sound. The following elementary treatment, for the case when the source is moving towards the observer, gives an approximately correct result.

"Suppose the source, S, and the observer, O [Fig. A], are relatively at rest at a distance apart of V, numerically equal to the velocity of light, *i. e.*, to the distance travelled by light in one second. A train of waves issuing from S will reach O at the end of one second, and if λ is the wave-length of the light, and n its frequency, then there will be n waves in the length SO, and we shall have

$$V = n\lambda.$$

Now suppose that, while the source is emitting waves, it is moving towards O with velocity v. Then, if it is at S at the beginning of the second, it will be at S' at the end, where $SS' = v$. The n waves emitted during the second will now be contained in a length $S'O = V - v$, for the first wave was emitted from S, and therefore would just

reach O in a second, as before. Consequently, the length of each wave must now be λ', where

$$V - v = n\lambda'.$$

From the two equations, we have at once $\dfrac{\lambda'}{\lambda} = \dfrac{V - v}{V}$; or, if the change of wave-length, $\lambda - \lambda'$, be denoted by $d\lambda$, we have $d\lambda = \lambda . \dfrac{v}{V}$. Now since the position of

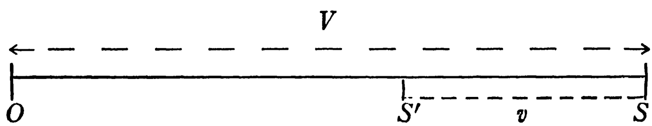


Fig. A

a line in the spectrum depends on the wave-length of the light in it, this change is equivalent to a shifting of the line towards the violet, compared with its normal position, by an amount depending on $d\lambda$. Knowing the normal wave-length of the light, λ, and the velocity of light, V, we can therefore, by measuring the shift, $d\lambda$, calculate v, the velocity of approach of the source. A similar treatment can be given to the case in which the source is receding from the observer, or the observer is approaching or receding from a stationary source. In every case, relative approach gives a displacement to the violet, and relative recession gives the opposite effect.

"This argument, which is apparently irrefutable, is, nevertheless, a false one; that is to say, the physical ideas it gives cannot represent reality. What we actually observe, in the light from a large number of stellar sources, is a displacement of the spectrum lines by amounts proportional to their wave-lengths. Assuming this to be due to relative motion in the line of sight, the 'line of sight' velocities of the stars are calculated, and figures are obtained which are consistent with what we should expect from more direct measures of velocity components. . . . There is very strong evidence, therefore, that a Doppler effect in light does exist, of the order calculated. But when

we consider the physical cause of the effect, we are on much more debatable ground. The explanation we have given throws the responsibility for the displacement on the actual light waves in the Ether. That this is not justifiable can be seen at once, when we remember that the displacement is found only when there is *relative* motion between the source and the observer. If, in our example, the observer, like the source, were to move to the left, with velocity v, the displacement would disappear, yet all we have said about the length of the waves would be unaffected. The Doppler effect arises only from the relations between the source and the observer; it has nothing to do with the source alone, or with the observer alone, or with the Ether between them. If we conceive of the Ether as an objective reality, and 'length' as an inalienable property of the waves it transmits, then we must absolve it from any responsibility for the Doppler effect. The whole matter receives a satisfactory explanation in the light of the theory of relativity, but it would take us too far afield to introduce that subject here."[30]

It is important to note several points in this passage: First, the statement that "For light waves, however, a proof [of the Doppler effect] quite so direct as this is not yet within the bounds of possibility" is incorrect. The author was evidently unaware of the experiments of certain Russian physicists, presently to be referred to, which show that the "explanation" of the relativity theory is opposed by something more conclusive than the explanation of another theory. Second, the statement "If, in our example, the observer, like the source, were to move to the left, with velocity v, the displacement would disappear," by which he attempts to show that the classical interpretation is "not justifiable," would be equally true if the waves were sound waves in air. Hence if it proves that the dis-

[30]Dingle, H., *Modern Astrophysics,* pp. 34, 36.

placement is not in "the actual light waves in the Ether," as he claims it does, then, in the case of sound, it would prove that the displacement is not in actual sound waves in the air—which would be proving altogether too much —much more in fact than the relativists wish to prove. For they do not admit that there are any "relativity" effects connected with sound waves. Third, the statement that "The Doppler effect arises only from the relations between the source and the observer" is entirely consonant with the claims of the relativists—and consonant also with those of the non-relativists if the word "only" is left out. The classical physicist maintains that another factor is essential, namely, a physical mechanism in the light which shall translate the motion of the source into an actual displacement of light waves relative to the medium and the source itself, a displacement, to be sure, which can be neutralized in the case of a given observer moving coincidently with the source, just as in the parallel case of sound waves; but a displacement, nevertheless, which is in the light waves in the same sense that a similar displacement is in sound waves subject to Doppler effects. That Dingle is correct in what he says about the relativity interpretation can be discovered by recalling once more the tenet of relativity, that light moves with the same velocity relative to a given body irrespective of the motion of the body itself. Hence it cannot shorten or lengthen the light waves in the line of motion in the manner described by Dingle in expounding the non-relativity interpretation. That a light source cannot change its velocity relative to its own radiation, as a sound source can, is maintained by Eddington, on grounds of relativity, as follows:

"It has often been suggested that the stars will be retarded by the back-pressure of their own radiation. The

idea is that since the star is moving forward the emitted radiation is rather heaped up in front of it and thinned out behind. Since radiation exerts pressure the pressure will be stronger on the front surface than on the rear. Therefore there is a force retarding the star tending to bring it gradually to rest. . . .

"But according to the theory of relativity 'coming to rest' has no meaning. A decrease of velocity relative to one frame is an increase relative to another frame. There is no absolute velocity and no absolute rest for the star to come to. The suggestion may therefore be at once dismissed as fallacious."[31]

Thus there can be no heaping up in front and thinning out behind of the light waves, when the source is moving, as there is in the case of sound. In short, the Doppler effect, according to the relativists, is, like the Lorentz shortening, and the increase of mass with motion, a purely "relativity" effect, "subjective" and having "no physical significance." That it is all a matter of the frame of reference from which observed is made plain by Eddington, when he says:

"You might perhaps think that there must be some qualitative difference between the quantum of red light and the quantum of blue light, although both contain the same number of erg-seconds; but the apparent difference is only relative to a frame of space and time and does not concern the absolute lump of action. By approaching the light-source at high speed we change the red light to blue light in accordance with Doppler's principle; the energy of the waves is also changed by being referred to a new frame of reference."[32]*

[31]Eddington, A. S., *The Nature of the Physical World,* pp. 58, 59.
[32]*Ibid.*, p. 184.

*This argument is indeed a revealing one, since it applies as much to sound as to light. If there is no "qualitative difference" between red light and blue because "by approaching the light-source at high speed

The actual derivation of the Doppler effect from the equations of relativity may be found in Jeffery, G. B., *Relativity for Physics Students,* pp. 90, 91, and in Tolman, R. C., *The Theory of the Relativity of Motion,* pp. 57–59. The methods of inferring the Doppler effect there applied, reveal very plainly the dimensional character of the relativity "explanation."

Keeping in mind this relativity interpretation of the Doppler effect, let us examine the bearing thereon of certain experiments conducted in the laboratory of the St. Petersburg Academy of Science near the beginning of the present century. Referring to them Wood says:

"The effect was first obtained in the laboratory of Bélopolsky in 1901 (*Astro. Phys. J.* 13, pg. 15–24), who reflected a beam of light from a system of moving mirrors, subsequently analyzing the light with a spectroscope. The displacement of the spectrum lines was of the calculated order of magnitude, which was, however, an exceedingly small quantity. . . . Bélopolsky made use of multiple reflections from two systems of mirrors, mounted on the rims of a pair of opposed wheels, which could be revolved at high speed."[33]

we change the red light to blue light in accordance with Doppler's principle," the energy of the light waves being likewise changed "by being referred to a new frame of reference," then there is no "qualitative difference" between a bass and a soprano note of music, because by approaching the sound source at high speed we change the bass note to the soprano in accordance with Doppler's principle, the energy of the sound waves being likewise changed "by being referred to a new frame of reference." In short, by applying the same dimensional process to sound, and substituting the velocity of sound for the velocity c of light in our definitions, we can place at the service of physics brand new kinds of "time" and "space," and by means of the "theory" thus established can annul these "qualitative" differences in sound as well as in light, and convert them all into the "subjective" or "relativity" kinds. This is an excellent illustration of where the relativity equations get their explanatory power. They are simply disguises for Doppler's principle.

[33] Wood, R. W., *Physical Optics,* pp. 23, 24.

This refers to the first production of Doppler effects in light by artificial means in the laboratory. He further says:

"The experiment was repeated in 1907 by Prince Galitzin and J. Wilip with Bélopolsky's apparatus. They employed an echelon spectroscope and the mercury arc, and obtained much larger shifts than those observed previously on account of the much greater power of the spectroscope."[34]

Note particularly that in these experiments multiple reflections were employed. Moreover, as the number of reflections on each moving mirror was six, and as reflection, according to the classical theory, produces a Doppler effect twice as great as emission, the effect was multiplied 12 times for a given rate of movement of the mirrors. It was by this multiplication, in short, *by the accumulation of the Doppler effect in the light,* that the effect was made great enough for detection by the means of observation employed. *And the results were in agreement with the assumption that the Doppler effects were thus additive.* These experiments are thus crucial in proving that the effect is a physical one in the light itself, just as in the parallel case of sound waves, and disproves the relativity contention that it "arises only from the relations between the source and the observer." For the mirrors which constituted the source in this case were moving relative to the spectroscope and photographic plate, which constituted the observer, with a maximum velocity of only one-twelfth that which, according to the relativity interpretation, should give the displacement recorded on the plate.[35] In

'., p. 24.

[35]Galitzin, B., and Wilip, J., *Bulletin of the Academy of Science of St. Petersburg,* VI series, vol. 1, 1907, p. 218.

other words, the relativity interpretation predicts only one-twelfth the result observed, while the non-relativity interpretation predicts 12 times as much as the relativity one. Thus the former is refuted and the latter confirmed *by the facts.* If the relativist seeks to meet this refutation by interpreting his interpretation so as to include the accumulation of his "subjective" effect in the light itself, then, not only the *Doppler effect* but the *contraction* and the *mass* of moving bodies would be subject to the same variation, and could be caused to have any value we pleased by the mere multiplication of light reflections from even very slow-moving bodies. And this would mean that they *all* depend upon something besides relative motion (and index of refraction)—a conclusion in direct conflict with the fundamental assumption of relativity.

No doubt by applying the relativity correction 12 times, the relativists would be able to make their equations fit these results, and thus be "verified" by the facts, because their corrections, being disguises for Doppler-displacements, follow the addition law of such displacements. But if asked why they should be applied 12 times despite the fact that the maximum relative material velocity involved is only one-twelfth that which this multiplication of their correction would assume, what answer could they give? Obviously their only answer would be that, in accordance with the usual classical assumption, and the facts, six reflections of light require them to do it. But though they have thus made their *equations* fit the facts, they have not made their *assumptions* fit them, since the assumption that time and space are functions of the number of reflections suffered by light is not to be found in the philosophy of relativity, and if adopted, would reduce the "theory" that it is all a matter of relative motion, to nothingness. It is

in fact appropriate to reiterate here the warning given in Chapter VI, that the successful application of the *equations* of relativity does not carry with it any verification of the *assumptions*. Indeed, the radiation theory predicts that the equations will be verified, so long as they are so adapted to the conditions of an experiment as to apply the correction called for by the Doppler-displacements, for which they are disguises. By applying them 12 times to the experiment of Galitzin and Wilip, for instance, they can be so adapted. That the equations can be made to fit the facts in this or in any other case then, proves nothing about the assumptions of Einsteinian relativity, any more than in the case of the kinds of relativity formulated to fit the facts of the *d*- and *l*-effects noted in Chapter II. It is important to remember this when seeking means of meeting the criticisms of the relativity assumptions to be found in this volume, and especially in this chapter.

From the evidence cited in this section then, it is safe to conclude that the question which it propounds is answered by the relativists in the affirmative and by the facts in the negative, which means that the basic assumption of the relativity theory about the relativity of motion is in disagreement with the facts.

Section 19. Are velocities greater than that of light possible?

That the theory of relativity fixes the velocity of light as the limiting velocity attainable in the universe is a statement affirmed by most relativists, denied by others, and regarded as uncertain by still others. Here, for instance, are some typical affirmations:

"In the theory of relativity the velocity c [that of light]

plays the part of a limiting velocity, which can neither be reached nor exceeded by any real body."[36]

"The chief importance of the velocity of light is that no material body can exceed this velocity."[37]

"From this ["this" meaning the fact that the Lorentz contraction makes the length of a rod zero when $v = c$] *we already conjecture that c represents an upper limit for all velocities of matter."*[38]

"That material velocities exceeding that of light are not possible, follows from the appearance of the radical $\sqrt{1 - v^2}$ in the special Lorentz transformation."[39]

"There are several ways by which it may be shown that a material body cannot have a velocity as great as that of light. One of these we used in §22 showing that, if a material body had a velocity greater than that of light, the numerical measure of length and time on that body would be imaginary, while if its velocity were just equal to that of light a given time interval would have an infinite measure.

"We may also prove the same theorem by means of a consideration of mass."[40]

And here are a couple of denials:

"It would not be inconsistent with the principle [of relativity], as stated at present, to suppose that a body might . . . be given a velocity greater than that of light relative to some other system."[41]

"As far as I can see, this ["this" refers to the same thing as in the quotation from Sommerfeld, above] does

[36]Einstein, A., *Relativity*, p. 36.
[37]Eddington, A. S., *Space Time and Gravitation*, p. 60
[38]Sommerfeld, A., *Atomic Structure and Spectral Lines*, p. 459.
[39]Einstein, A., *The Meaning of Relativity*, p. 42.
[40]Carmichael, R. D., *The Theory of Relativity*, p. 60.
[41]Campbell, N. R., *Modern Electrical Theory, Chapter XVI Relativity*, p. 21.

not necessarily mean that motion with hypervelocity [*i. e.,* a velocity exceeding that of light], of one body relative to another, is 'impossible.' "[42]

In passing it is worth noting that Silberstein's, like Einstein's and Carmichael's (opposite), conclusion with regard to this question, quite evidently turns on his interpretation of the behavior of a mathematical equation on substituting a certain value for one of the variables. This exemplifies the method of reasoning of relativists in general. Their conclusions are based on the behavior of equations rather than the behavior of nature.

The issue raised by the above quotations relates to the question of whether the relative motion of *material bodies* can exceed the velocity of light, and it is obvious that there is disagreement about the matter, amounting in fact to flat contradiction. But the question may be raised of whether the velocity of light is a limiting one on the motion of *matter* or on *something else.* On this question the relativists are somewhat at sea, but the following excerpts are significant, especially when we have in mind the alternative of the radiation theory, which postulates unbalanced radiation pressure as the cause of change of material motion.

Thus Tolman in his *Theory of the Relativity of Motion,* pp. 54, 55, referring to a mathematical demonstration based on relativity in which "some impulse originates at *A*, travels to *B* with the velocity *u,* and at *B* produces some observable phenomenon," the impulse at *A* and the "resulting phenomenon at *B* thus being connected by the relation of *cause and effect,*" raises the question of what would be observable on a system S' moving with a velocity V relative to the system on which *A* and *B* are situated, if *u*

[42]Silberstein, L., *The Theory of Relativity,* p. 114.

were greater than the velocity of light, and comes to the following conclusion:

"For an observer in system S' the effect which occurs at B would *precede* in time its cause which originates at A. Such a condition of affairs might not be a logical impossibility; nevertheless its extraordinary nature might incline us to believe that no causal impulse can travel with a velocity greater than that of light."

Here the limiting velocity is not that of material bodies, but of "causal impulse." To further illustrate the state of mind of relativists on this point, consider the following statement of Eddington:

"It may be asked whether it is possible for anything to have a speed greater than the velocity of light. Certainly matter cannot attain a greater speed, but there might be other things in nature which could. 'Mr. Speaker,' said Sir Boyle Roche, 'not being a bird, I could not be in two places at the same time.' Any entity with a speed greater than light would have the peculiarity of Sir Boyle Roche's bird. It can scarcely be said to be a self-contradictory property to be in two places at the same time any more than for an object to be at two times in the same place."[48]

Perhaps the reader may be disposed to reflect upon the confusion exemplified in this and many other passages quoted herein, and to consider what his verdict would be if the theory which involved such statements were not the specially privileged relativity theory, but a geographical or geological or biological theory, the first requirement of which is respect for the facts of observation, and care in the avoidance of contradictions.

Turning now to the radiation theory for comparison we find that in its answer to this question there is no more

[48]Eddington, A. S., *Space Time and Gravitation,* p. 60.

equivocality than to the questions previously discussed. Briefly, its position is as follows:

Two material bodies can move relatively to one another faster than the velocity of light, and two causal impulses can do so also. When two cathode ray streams (of electrons) having a velocity through their tubes more than half that of light pass one another, going in opposite directions, their relative velocity is greater than that of light, and two light waves in vacuo moving in opposite directions pass one another with a velocity twice that of light—and a light-wave is a causal impulse. The velocity of causal impulses *relative to the ether,* however, is limited by the velocity of radiation relative thereto. Hence, normally at any rate, the velocity of causal impulses is limited by the velocity of light of 186,000 miles per second. But any condition which would facilitate the rate of energy interchange between radiation and the medium through which it is moving, whether including matter or not, would permit radiation, and therefore causal impulses, to travel faster than 186,000 miles per second relative to the ether. Whether such conditions are to be met with in nature is something for the facts to decide, and apparently they decide in the affirmative. For the index of refraction for ordinary light of metallic films and vapors, and in any medium for frequencies in close proximity to their absorption bands, is less than one. The index for X-rays in most or all media is also less than one. These facts give us excellent reasons for believing that the velocity of light in material media may, under certain conditions, exceed that of light in vacuo. Indeed, I know of no interpretation of these fractional indices which does not involve such a conclusion. These facts are not in conflict with the radiation theory, since that theory does not connect the velocity

of light with time and space in any more hard and fast manner than the velocity of sound. Whether they are in conflict with the theory of relativity is uncertain, since it depends upon the "interpretation" of the theory that is accepted. They would surely be in conflict with the contentions of those who claim that causal impulses cannot move faster than 186,000 miles per second. In the next section it will be shown that Eddington, while admitting the inference from fractional indices here maintained, seeks (unsuccessfully) to deny that *signals* can be transmitted at a faster rate than in empty space. The boggle there discussed is relevant also to this section, but cannot without repetition be inserted here, because it does not resemble Sir Boyle Roche's bird, or light variations traversing media with fractional indices of refraction, in ability to be "in two places at the same time."

The relativists themselves are so much at sea on this whole question that there seems no clear way of deciding whether the facts are irreconcilable with their assumptions or not. But at least it may be said that to define time and space by means of signals having the velocity that light happens to have in vacuo, is to define them in a manner less simple, and less fundamentally related to the nature of things, than is generally assumed by the relativists; certainly less simply related thereto than to define them by means of signals moving with infinite velocity, as Newton does. For if they are defined by means of impulses moving with the velocity of a physical agent like light, they will be functions of that velocity, and subject to all the variations (with refractive index, etc.) to which it is subject. Indeed, to define them by means of any finite velocity, and then fail to correct for the particular velocity selected, is an arbitrary proceeding, of which a conse-

quence is sure to be confusion; whereas to define by means of an infinite velocity avoids all arbitrariness and associated need for correction. It is not to be denied, of course, that the velocity of light in vacuo is a highly significant magnitude in nature, a fact recognized, indeed predictable from, the radiation theory. But its significance, according to that theory, is due to the characteristics of "vacuous" space which determine that velocity, and not to any relation between space and time unknown to the Newtonians.

Section 20. Has the theory of relativity superseded the law of causation?

According to many authorities, the theory of relativity is in conflict with the law of causation. There is, to be sure, much confusion about the matter, but some relativists accept the conflict, others deny it and others appear to be non-plussed. The passages proving this contention are too lengthy to be cited here, but anyone caring to verify it can do so by reference to the following citations, among others: Russell, Bertrand, *The A B C of Relativity,* pp. 205–231; Campbell, Norman, *Modern Electrical Theory, Chapter XVI Relativity,* pp. 11–12; Bridgman, P. W., *The Logic of Modern Physics,* pp. 86–87; Tolman, R. C., *The Theory of the Relativity of Motion,* p. 55. It will suffice here to give some briefer citations, the consistency of which with more extended ones may be readily verified. For instance:

"The language of cause and effect . . . is . . . merely a convenient shorthand for certain purposes; it does not represent anything that is generally to be found in the physical world."[44]

[44]Russell, Bertrand, *The A B C of Relativity,* p. 205.

resentation may thus be not completely adequate, but it suffices for all that comes within the purview of physics."[49]

This statement to be sure is confusing. Eddington expresses sympathy with experience but appears to find no place for it in "the determinate equations of physics," implying that this places "what appears to be the ordinary experience of life" in an embarrassing position. Some physicists would be inclined to conclude that the embarrassing position is that of the "determinate equations," but to the mathematician the symbol is likely to assume an importance greater than the thing symbolized. Nevertheless, Eddington seems rather non-plussed by the dilemma in which the theory of relativity places physics. It is not quite plain whether physics is in conflict with the law of causation, or whether "the ordinary experience of life" is a matter not "within the purview of physics." But the acceptance of one or the other alternative would seem from Eddington's statements inevitable, and either is equally fatal to his brand of physics, since acceptance of the first would render its statements false, and of the second useless and irrelevant to experience. Eddington, however, would appear to incline to the first horn of the dilemma (thus agreeing with Weyl) since he states plainly that by the simple process of changing "the place of one particle" we are able to alter the past—to retract some act in our past life for instance. If this is so the law of causation has certainly been superseded. But when we realize the dimensional character of the relativity equations we see that this is all a verbal hocus-pocus. It is not the law of causation which has been changed. It is merely the mean-

[49]Eddington, A. S., *Report on the Relativity Theory of Gravitation*, p. xi.

ings of the words "past," "present" and "future," caused by the changed meaning of the word "time." In short, these blind inferences from the relativity equations cause the theory of relativity to appear to be saying what it is not saying at all, and thus the relativists either deceive or non-plus themselves and others. If this is not so, we have only to "change the place" of the proper particle or particles to alter that part of the past in which the theory of relativity was discovered—and the theory may thereby be caused to disappear, together with its discoverers. If everything depends upon a "point of view" of this kind, the truth of the theory of relativity itself must so depend —and of the multiplication table also, for that matter. When physics reaches such a stage as this it reverts to the chaos of unreason, and all distinction between the true and the untrue disappears. Thus we are forced to conclude that either these statements of the supersession of the law of causation, and the analogous statement of the possibility of a thing being in two places at the same time (see Section 19), are the result of mere verbal mix-ups, or that relativity is incompatible with reason. Of these two alternatives, the former is the correct one.

To illustrate how these ambiguities confound scientists and paralyze their critical faculties, let us consider an illuminating example furnished by Eddington, who furnishes so many. What he calls "that topsy-turvydom of past and future, of which Einstein's theory is sometimes wrongfully accused" (see quotation following) apparently irks him, so he seeks a modification of it less glaringly at variance with experience. But in doing this he encounters one of those stubborn facts of physics which are so annoying to the speculator, and in trying to avoid

it, collides with another equally stubborn, which wrecks his scheme of space, time and causation as completely as the first one. But the pursuit of his theory has so paralyzed his critical powers that he does not even discover the wreck. Here is how he does it:

"Neither *matter,* nor *energy,* nor anything capable of being used as a *signal* can travel faster than 299,796 kilometres per second, provided that the velocity is referred to one of the frames of space and time considered in this chapter.*

"The velocity of light in matter can under certain circumstances (in the phenomenon of anomalous dispersion) exceed this value. But the higher velocity is only attained after the light has been passing through the matter for some moments so as to set the molecules in sympathetic vibration. An unheralded light-flash travels more slowly. The speed, exceeding 299,796 kilometres a second, is, so to speak, achieved by prearrangement, and has no application in signalling.

"We are bound to insist on this limitation of the speed of signalling. It has the effect that it is only possible to signal into the Absolute Future. The consequences of being able to transmit messages concerning events Here–Now into the neutral wedge are too bizarre to contemplate. Either the part of the neutral wedge that can be reached by the signals must be restricted in a way which violates the principle of relativity; or it will be possible to arrange for a confederate to receive the messages which we shall send him to-morrow, and to retransmit them to us so that we receive them to-day! The limit to the velocity of signals is our bulwark against that topsy-turvydom of past and future, of which Einstein's theory is sometimes wrongfully accused. . . .

"To violate it [limitation of the speed of signalling to 299,796 kilometres a second] we have not merely to find something which goes just 1 kilometre per second better, but something which overleaps that distinction of time

and space—which, we are all convinced, ought to be maintained in any sensible theory."[50]

*"Some proviso of this kind is clearly necessary. We often employ for special purposes a frame of reference rotating with the earth; in this frame the stars describe circles once a day, and are therefore ascribed enormous velocities."

By noting what is said in the second paragraph of this passage, it will be found that Eddington has wrecked his own theory of space, time and causation, and thus himself achieved the consequence "too bizarre to contemplate" so calmly accepted by Weyl. For he recognizes that the discovery of fractional indices of refraction is a fact too stubborn to permit the claim that causal impulses cannot travel faster than 299,796 kilometres a second. That is, he recognizes that light waves are causal impulses, and that they travel relative to certain media at a greater velocity than this, but he rests the validity of his theory on the supposed fact (?) that "signals" cannot be transmitted at a greater velocity than in vacuo, a rather shaky foundation for a theory on which so much depends, and rendered even more so by his tacit assumption that a signal can only be transmitted by "an unheralded light-flash." It is not at all clear why this distinction between signals and causal impulses as the things which cannot move faster than light in vacuo, is an important, or even a relevant one, but even assuming that it is, Eddington in pinning his faith to the "unheralded light-flash" as the only possible means of transmitting signals is grasping at straws in the effort to save his theory from the fate of Weyl's and Russell's. For if we pause to reflect, it will become clear that a light-flash of this character is not the only kind of signal transmissible by means of light. Various alternatives are pos-

[50]Eddington, A. S., *The Nature of the Physical World*, pp. 57, 58.

sible, and one or two are very obvious. The light ray may be uninterrupted and signals transmitted by varying the polarization, for instance. Again, it is well known that in dispersive media refractive indices are functions of wavelength, but not of intensity. Hence it is possible to transmit a signal through a medium having a fractional index of refraction by merely varying the intensity thereof. In either manner *signals* travelling at a velocity greater than 299,786 kilometres a second can be transmitted, which wrecks Eddington's theory of past and future as completely as the discovery of fractional indices wrecks the theory of those who deny that causal impulses can travel with a greater velocity than this. Hence the "bulwark" he sets up breaks down, and according to his own admission, his curious theory of the "neutral wedge" cannot be a "sensible theory," since it rests upon a foundation as illusory as other theories of the "topsy-turvydom of past and future."

If then Eddington is correct in asserting that "We [relativists] are bound to insist on this limitation of the speed of signalling," the discovery of fractional indices of refraction constitutes a refutation of the relativity assumption about time unless some "interpretation" of such indices differing from that of Eddington and of physicists in general is permissible. But no alternative view appears to have been suggested, even by the relativists. Moreover, the usual interpretation of indices greater than one is not only accepted by relativists, but must be accepted if the result of the Fizeau experiment is to be claimed as confirmatory of the theory of relativity. It will be noted on page 41 that Einstein is able to maintain this claim only by assuming the velocity w as the velocity of light in water. This velocity, however, is inferred from the index

of refraction of water in the usual manner. Thus when the usual interpretation of refractive indices is in agreement with the relativity theory, it is accepted. On what grounds then can it be rejected when in disagreement? There appear to be none unless facts are to be invented to fit a theory instead of a theory to fit the facts.

In passing it may be noted that the reversal of time is probably not the only difficulty which the discovery of fractional indices of refraction causes the assumption of relativity. When a fundamental dimension like time becomes negative, what happens to its derivative magnitudes, velocity, energy, etc.? Do they not become negative also? Or only imaginary? At any rate, something evidently happens to all Einsteinian magnitudes which places them in the class of things "too bizarre to contemplate."

If we turn to the interpretation of the relativity equations suggested by the radiation theory, all this perplexity and paradox disappears. There is no conflict with the law of causation, whether due to verbal confusion or to misinterpretations of our experience more fundamental than verbal ones. There is no reversibility of the flow of time, and neither by our acts, nor by any other means, can the past be affected by what occurs in the present. It is not time that reverses. It is only a Doppler-displacement.

By comparing the meanings of Newtonian and Einsteinian simultaneity stipulated in Chapter I, the origin of the notion that time can, under certain circumstances, be reversed, and hence causal agencies operate from future to past, will become apparent. Perhaps the simplest way of grasping the origin of the paradox is to imagine an observer on a railroad embankment listening to the whistle of a locomotive approaching him at high speed. As long

as the velocity of the locomotive is less than that of sound, the sound waves which strike his ear will strike it in the same order in which they are emitted, although at a faster rate and hence at a higher pitch. In this case the Doppler-displacements will be of the normal kind with nothing paradoxical about them. But suppose the locomotive to move with a velocity greater than that of sound. How then will the sound waves, and signals transmitted by them, strike the ear of the observer? Very differently. They will strike his ear in the reverse order from that in which emitted. In other words, the last waves emitted will appear to him to be the first and the first ones last. And if he judges the direction of the flow of time by the order in which sound signals reach him, he will, of course, judge that it has been reversed, and is now running backwards, so that effects can precede their causes in a paradoxical manner. If, however, he had a means of observing sound signals by means of some agency moving with the velocity of light, he would be able to see that the paradox arose from a misinterpretation of the behavior of a Doppler-displacement, a misinterpretation which is bound to occur as long as the displacement is observed by means of signals which move with the velocity of the sound waves themselves. As the velocity of light is, for practical purposes, infinite compared with that of sound, such an observer would be an analogue of a Newtonian observer, whereas the observer using ordinary sound waves as a means of observation would be the analogue of an Einsteinian observer (see Chapter I, pages 16 and 18).

Now if the radiation theory is correct in its assumption that causal impulses in gravitational and electromagnetic fields move with the velocity of light, then if a radiation-emitting source moves, relative to its own radiation, faster

than the waves which it is emitting, it is possible for an observer—in certain co-ordinate systems—to receive those waves in reverse order, and if he judges the direction of flow of time by the order in which he receives them, he will judge the causal impulses to be operating in reverse order, and hence time to be flowing backward, just as in the parallel case of the observer listening to the locomotive whistle. But if he could observe by means of some agency moving with a velocity practically infinite compared with the velocity of light (a Newtonian agency), such misjudgment of the Doppler-displacement would not occur, and he would see that his paradoxes arose from the fact that he was observing by means of signals moving with the same velocity as the causal impulses, but failing to make allowance for that fact. Now it is a fundamental principle of relativity that all judgments of time, length, velocity, acceleration, mass, etc., shall be those of an observer observing by means of light signals, and making no allowance for their velocity, since to the Einsteinian the velocity of such signals corresponds to the infinite velocity of the Newtonian; and imagine the paradoxes that the Newtonian would encounter if he assumed himself to be receiving signals transmitted by an agency moving with a velocity greater than an infinite one! In short, to the Einsteinian, as we have seen, there is no greater velocity possible than that of light. Beyond such a velocity all is paradox. Thus if the radiation theory is sound, the method of observation, and judging from observation, prescribed by Einstein, must necessarily lead to the very "topsy-turvydom of space and time" that we find it leading to, since the relativist is observing radiational effects by means of an agency (light) which moves with the same velocity as the effects themselves. The "topsy-turvydom,"

indeed, is the same as that which would beset an observer attempting to judge sound effects exclusively by means of signals moving with the velocity of sound. From these considerations the origin of the relativity paradox about causation is plain. Recognition of the two different meanings of simultaneity distinguished in Chapter I reveals it. And, like all other paradoxes of relativity, it turns out to be caused by the misinterpretation of a Doppler-displacement. It is not time, length and their derivatives which reverse themselves in so bizarre a manner when bodies move with a velocity greater than light. It is the magnitude whose relativity has been mistaken for that of time and length, namely, a Doppler-displacement, and its reversal under such circumstances is not only natural, but necessary. Thus again, from an entirely different approach, we encounter, and are able to identify, the non-dimensional explanation for which the definitions of relativity are disguises.

Although the radiation theory disagrees with the assumptions of relativity concerning the relation of cause and effect, it has something positive to suggest about causation, and something perhaps of no small importance. It proposes a unity in the infinite complexity of causes presented to our experience which is at least a clue worth following. Change in the material world, at least since the time of Newton, has been attributed to "force," and the radiation theory supplies us with a definite physical meaning for that word. Force exists wherever unbalanced radiation pressure exists. Hence a cause of change of motion in the material world exists wherever unbalanced radiation pressure exists, and no cause of change exists where radiation pressure is balanced. Force then, as well as energy is dynamic, a conclusion reached by Tait half a

century ago (see page 91). Thus the radiation theory reveals, perhaps, a far-reaching identity amid the diversity of material change in the universe. It suggests a single explanation or cause for all change of motion, applicable to all "frames of reference," whether in relative motion or not. It does not, to be sure, provide us with any near approach to certainty in the matter, nor does it pretend to knowledge of parts of the universe remote from our observation. But it proposes a convenient working hypothesis about the universal nature of force, consistent with the law of causation, and so far as known, with all other facts of experience, and until some more plausible hypothesis is proposed, it would seem worthy of serious consideration. Its operations, at any rate, can never be replaced or superseded by any set of equations, however ingenious.

Section 21. Are gravitation and inertia identical?

Before entering upon the discussion of this question it will be well to recall a few definitions and facts.

As physicists use the word, gravitation is the name of the force by which uncharged and unmagnetized material bodies are urged toward one another. It is a property of bodies by virtue of which they tend to change their rate of motion relative to one another. The law of variation of this tendency with the distance between the gravitating bodies is expressed by the well-known inverse square law of Newton, and is obeyed by the members of the solar system.

As physicists use the word, inertia is the name of a property of material bodies by virtue of which they tend to resist change in their rate of motion relative to the ether. Were there no such property of bodies, their motion

would, for all we know, change instantaneously, and perhaps to an infinite degree, by the application of any force, however small. The law of this tendency is expressed by the statement that the inertia of a body does not vary at all. This law is also obeyed by members of the solar system. These statements of the variability of gravitation with distance and of the invariability of inertia are, as already pointed out, not strictly accurate, since the latter, and probably the former, are affected by motion, though at ordinary velocities to an inappreciable degree. Thus qualified, the statements relate simply to the observed or inferred behavior of material bodies. They are entirely independent of any statements about "mass." They do not in fact include that word, which, in the writings of modern physicists, is highly equivocal, and hence likely to mislead, just as the equivocalized words "time" and "length" do. Indeed, the meanings of all three of the fundamental dimensions of physics have been rendered so ambiguous by the recent intrusion of metaphysical methods into physics as to be highly dangerous to inference.

One other fact may be recalled before we proceed. Aristotle claimed that the heavier a body is the faster it will fall. Apparently he reasoned something like this: A heavy body tends downward more than a light one, that is, the force urging it downward is greater. Hence it will fall faster. His claim could have been experimentally refuted by any boy dropping two stones differing in weight from the roof of his father's barn. Yet it was accepted by all men, philosophers and scientists included, for 2,000 years! Which illustrates the disposition, even of the best minds, to overlook the obvious if it is opposed by prevailing authority, a disposition not confined to the past.

Finally, about 1590, Galileo got into very bad favor with the physicists of his time by simultaneously dropping two shot, differing in weight, from the leaning tower of Pisa, which struck the ground at the same time, thereby proving that they fell with the same velocity. Thus he discovered the first of that long series of compensation effects which beset all things radiational—for matter was a radiational phenomenon in Galileo's time just as it is to-day. Despite the fact that the heavy shot was urged downward by a greater force than the light one, it fell no faster, because the greater force was exactly balanced by the greater reluctance of the larger shot to be accelerated by a force. In short, he discovered that inertia is proportional to gravitation—certainly a remarkable discovery, though an empirical one—and since his day this truth has been everywhere recognized though not explained. But the fact that gravitation and inertia are proportional does not mean that they are identical. The weight of a piece of wire is proportional to its length, but that does not mean that the weight is identical with the length. It is, in fact, quite important to note just what Galileo's law says and what it does not say. It says that (*a*) the ratio of gravitation and inertia is independent of the amount or kind of matter in a body. It does not say that (*b*) the ratio is independent of the proximity or mass of neighboring bodies. Galileo discovered the compensation expressed in (*a*). Neither he, nor anyone else, ever discovered the compensation expressed in (*b*). If then, gravitation and inertia are found to be identical, it must be on other grounds than those provided by Galileo's discovery.

Having recalled the above facts and definitions, let us proceed to some statements of the relativists about gravitation and inertia. Consider the following for example:

"Gravitational force is not an active agent working against the passive tendency of inertia. Gravitation and inertia are one. . . . This identification of inertia and gravitation as arbitrary components of one property explains why weight is always proportional to inertia."[51]

"Inertial and gravitational masses are identical in nature."[52]

"The *same* quality of a body manifests itself according to circumstances as 'inertia' or as 'weight' (lit. 'heaviness')."[53]

Now we have already seen that gravitation is the name of a tendency of matter to change its rate of motion, and inertia the name of a tendency of matter to resist change in its rate of motion. By definition, therefore, these two properties of bodies are very different things. Yet the relativists tell us they are identical. Evidently then there is some verbalism in this "discovery." It is reminiscent of the mode by which it was "discovered" that (relative) time and space are relative. As the method of making this discovery is fundamental in the general theory of relativity and illustrates a method of making discoveries typical of, but not confined to, the relativists, let us describe the method in the words of the discoverer himself. In *Relativity,* Section 20, pp. 66–69, Einstein discloses his mode of reasoning, as follows:

"We imagine a large portion of empty space, so far removed from stars and other appreciable masses, that we have before us approximately the conditions required by the fundamental law of Galilei. It is then possible to choose a Galileian reference-body for this part of space

[51]Eddington, A. S., *Space Time and Gravitation,* p. 137.
[52]Weyl, H., *Space—Time—Matter,* p. 307.
[53]Einstein, A., *Relativity,* p. 65.

(world), relative to which points at rest remain at rest and points in motion continue permanently in uniform rectilinear motion. As reference-body let us imagine a spacious chest resembling a room with an observer inside who is equipped with apparatus. Gravitation naturally does not exist for this observer. He must fasten himself with strings to the floor, otherwise the slightest impact against the floor will cause him to rise slowly towards the ceiling of the room.

"To the middle of the lid of the chest is fixed externally a hook with rope attached, and now a 'being' (what kind of a being is immaterial to us) begins pulling at this with a constant force. The chest together with the observer then begin to move 'upwards' with a uniformly accelerated motion. In course of time their velocity will reach unheard-of values—provided that we are viewing all this from another reference-body which is not being pulled with a rope.

"But how does the man in the chest regard the process? The acceleration of the chest will be transmitted to him by the reaction of the floor of the chest. He must therefore take up this pressure by means of his legs if he does not wish to be laid out full length on the floor. He is then standing in the chest in exactly the same way as anyone stands in a room of a house on our earth. If he release a body which he previously had in his hand, the acceleration of the chest will no longer be transmitted to this body, and for this reason the body will approach the floor of the chest with an accelerated relative motion. The observer will further convince himself *that the acceleration of the body towards the floor of the chest is always of the same magnitude, whatever kind of body he may happen to use for the experiment.*

"Relying on his knowledge of the gravitational field (as it was discussed in the preceding section), the man in the chest will thus come to the conclusion that he and the chest are in a gravitational field which is constant with regard to time. Of course he will be puzzled for a moment as to why the chest does not fall in this gravitational field.

Just then, however, he discovers the hook in the middle of the lid of the chest and the rope which is attached to it, and he consequently comes to the conclusion that the chest is suspended at rest in the gravitational field.

"Ought we to smile at the man and say that he errs in his conclusion? I do not believe we ought to if we wish to remain consistent; we must rather admit that his mode of grasping the situation violates neither reason nor known mechanical laws. Even though it is being accelerated with respect to the 'Galilean space' first considered, we can nevertheless regard the chest as being at rest. We have thus good grounds for extending the principle of relativity to include bodies of reference which are accelerated with respect to each other, and as a result we have gained a powerful argument for a generalized postulate of relativity.

"We must note carefully that the possibility of this mode of interpretation rests on the fundamental property of the gravitational field of giving all bodies the same acceleration, or, what comes to the same thing, on the law of the equality of inertial and gravitational mass. If this natural law did not exist, the man in the accelerated chest would not be able to interpret the behavior of the bodies around him on the supposition of a gravitational field, and he would not be justified on the grounds of experience in supposing his reference-body to be 'at rest.'

"Suppose that the man in the chest fixes a rope to the inner side of the lid, and that he attaches a body to the free end of the rope. The result of this will be to stretch the rope so that it will hang 'vertically' downwards. If we ask for an opinion of the cause of tension in the rope, the man in the chest will say: 'The suspended body experiences a downward force in the gravitational field, and this is neutralised by the tension of the rope; what determines the magnitude of the tension of the rope is the *gravitational mass* of the suspended body.' On the other hand, an observer who is poised freely in space will interpret the condition of things thus: 'The rope must perforce take part in the accelerated motion of the chest, and it transmits

this motion to the body attached to it. The tension of the rope is just large enough to effect the acceleration of the body. That which determines the magnitude of the tension of the rope is the *inertial mass* of the body.' Guided by this example, we see that our extension of the principle of relativity implies the *necessity* of the law of the equality of inertial and gravitational mass. Thus we have obtained a physical interpretation of this law.

"From our consideration of the accelerated chest we see that a general theory of relativity must yield important results on the laws of gravitation. In point of fact, the systematic pursuit of the general idea of relativity has supplied the laws satisfied by the gravitational field."

In this quotation it is particularly important to note the sentence beginning: "Guided by this example," for if Einstein is "guided by this example" then he is evidently inferring something from it, and his mode of inference is worthy of close inspection, since the soundness of the general theory would appear to rest upon it. On inspection we note, in the first place, that there is nothing in the example which does not follow from laws of physics known long before the time of Einstein. That acceleration, relative to the ether, in the absence of gravitation, is capable of producing the specified inertial effects, and that these effects are identical with gravitational effects, is inferable from classical laws of mechanics without any extension thereof, and in the passage quoted, Einstein is simply calling attention to this fact. But in inferring from this fact Einstein at once raises the issue of the justification for his inference. His inference is a generalizing one, as follows: Premise: Gravitation and inertia are identical in producing the effects described in the example. Conclusion: Therefore they are identical in all respects. The confirmatory citations from Eddington and Weyl, pre-

viously quoted, to the effect that inertia and gravitation are "one" or "identical in nature," simply state the conclusion of this inference. It is a conclusion to which relativists, "guided by this example," have come. Now no one will dispute the premise, but can such a premise support such a conclusion? Not if the rules of logic are sound.

The argument of Einstein which we are considering is obviously an argument from analogy—a favorite mode of argument among non-Euclideans—and it has all the weaknesses of analogical arguments in general. The form of arguments from analogy is as follows: Two things are alike in certain respects. Therefore they are alike in certain other (or perhaps all) respects. Mars is like the earth in many specifiable respects. Therefore it is like the earth in being inhabited. Spherical and plane triangles are alike in a number of respects. Therefore they are alike in the number of degrees which measure the sum of their angles. Time intervals are like length intervals in certain respects. Therefore they are like them in being "dimensions" (hence time is a fourth dimension). (Minkowski's argument.) Man is like a watch in being a mechanism. Therefore he is like a watch in being the creation of a mechanic. (Paley's argument.) Inertia is like gravitation in certain specifiable respects. Therefore it is like it in all respects. (Einstein's argument.)

Now it is well known to logicians that analogical arguments can be depended upon only if the two things between which analogy is noted are compared as carefully with respect to their dissimilarities as with respect to their similarities, and inference made accordingly. Failure to observe this rule leads to fallacious conclusions, and Einstein—in common with non-Euclideans generally—has failed to observe it. In the quotation under discussion he

has pointed out certain fundamental similarities between gravitation and inertia. Let us now point out certain dissimilarities no less fundamental.

Suppose we perform two experiments on a typical material body—say a standard kilogram weight—at the equator by means of a sufficiently sensitive spring balance of ordinary type. First, we weigh the body by means of the balance, and find that the weight as recorded is x divisions on the scale of the balance. This measures the force due to gravity at the equator tending to accelerate the body. Second, we measure the inertia of the body, by first suspending it in a suitable manner, or placing it on a horizontal frictionless surface, and observing what extension of the spring exerted for one second in a horizontal direction is required to give it a velocity of n centimetres a second. Assume this extension is y divisions on the scale. This measures the force due to inertia at the equator tending to resist the acceleration of the body. Suppose we now remove the body and balance to the Pole or to any high latitude and repeat the experiments. We shall then get x plus a small amount in the first experiment, and y plus or minus nothing in the second. In other words, the gravitation of the body has increased but its inertia has remained the same. This is, of course, a fact well known to physicists. Innumerable pendulum experiments, for instance, confirm it. A pendulum swings faster in high latitudes than in low ones, which could not be the case if the force of gravitation tending to accelerate the swing, and that of inertia tending to resist the acceleration, remained the "same" or "identical." For if they did, the two tendencies would compensate and the rate of swing of a pendulum would be independent of latitude—which it is not. From these and many other facts we conclude

that the magnitude of the gravitation of a body is a function of its proximity to other bodies, and of the size of those bodies, but its inertia is a function of neither. Here then is one fundamental dissimilarity between them. Let us turn to another.

Suppose we suspend a rod by a string at some point removed from its centre of gravity. It will then, under the influence of gravity, hang in a direction removed from the horizontal. If now we disturb its position—by raising the lower end for instance—it will, on release, presently return to its original position again. Suppose now we set up a Foucault pendulum in the usual manner, and set it swinging in the direction Earth—Polaris. It will maintain that direction as long as it swings, independent of the latitude and of the rotation of the earth. If now we stop it and set it swinging again in a different direction, say at right angles to the line Earth—Polaris, it will maintain the new direction just as persistently. Unlike the suspended rod in the first experiment, it will not tend to return to any particular position, either with relation to the earth or to the fixed stars. From this and many like facts we conclude that the direction (as well as magnitude) of gravitation is affected by the presence and proximity of other bodies, whereas the "direction" of inertia is as independent thereof as is its magnitude. Indeed, the dependence of gravitation upon the proximity of other bodies, and the independence of inertia, is conclusive proof of fundamental dissimilarities between them.

Now Einstein in his analogical argument has ignored these dissimilarities. Hence his inference that the two things are in reality "the same," is fallacious, the fallacy being due to defective analogy. Gravitation and inertia are similar in the respect which Einstein specifies—a fact

which Newton knew—but they are not similar in all respects, and hence cannot possibly be "identical." Obviously, we may if we please ignore these dissimilarities and coin a new term, such, for instance, as "inertia-gravitation" (see page 243) which shall refer to the similarity only, but though we may thus banish the distinction between gravitation and inertia from language, we do not banish it from experience. It still remains observable to beings qualified to observe. And any cosmological theory dealing with the observable behavior of bodies which fails to recognize the distinction is leaving a large gap in its cosmology. The value of an analogy is to be measured as much by what it ignores as by what it emphasizes.

Perhaps a somewhat different way of presenting the foregoing argument will show more clearly the curious relation between the theory of relativity and the facts.

Suppose we have a ball of clay whose gravitation and inertia we test by means of a spring balance in the manner previously suggested. Suppose now we decrease or increase the size of the ball by removing or adding clay. We shall always find that the change in gravitation and inertia are proportional. Moreover, we may add any kind of material to the ball, metal, wood, glass, or anything else, and the change in gravitation will always be compensated by a change in inertia, irrespective of the kind or amount of matter added. In short, by this expedient, we cannot cause the one to change without causing the other to change also, and to change proportionally. This is Galileo's law.

But now suppose we remove the ball of clay from a lower to a higher latitude, and again test it by the spring balance in the manner suggested. And, for the sake of the argument, let us suppose that the gravitation and inertia

remain proportional, despite the fact that geodetic measurements prove the earth to be an oblate spheroid. Would not this fact be in agreement with the relativity theory and be emphasized by the relativists as confirming it? It would if Einstein's reasoning about the identity of gravitation and inertia is correct, for it would show that, despite the departure of the earth from a perfect sphere, whatever happens to the gravitation happens to the inertia also. The one cannot change without the other changing in a compensating degree, just as in the first-named method of changing the gravitation of the ball. If the facts showed this compensation, the relativity theory would certainly be confirmed and the radiation theory refuted. It would indicate that the "curvature of space" at the point of test had the same effect on inertia as on gravitation, just as the theory of relativity requires.

But the facts are exactly the opposite. By this change of *position* of the ball, something happens to the gravitation, but nothing happens to the inertia. They do *not* remain proportional. Does this fact confirm the relativity theory also? If so, it must be a hard theory to refute by means of facts, since it fits diametrically opposed facts equally well. It is confirmed if the inertia does change with the gravity, and it is confirmed if it doesn't. What kind of reasoning is this?

Another point pertinent to the claim of the relativists here presented is that, if no absolute frame of reference relative to which the change of motion of a body occurs is postulated, the inertial mass thereof becomes a purely relative* property, having no relation whatever to its gravitational mass. Indeed, the inertial mass of any two bodies caused to change (accelerate) their relative motion

*See quotation from Preston, page 94, where this same kind of "relativity" is referred to.

will be the same, irrespective of what their gravitational mass may be. To prove this, assume two bodies, *A* and *B*, of unequal gravitational mass, and in order to be specific, suppose *A* to weigh one pound and *B* a million pounds. Then any force applied to body *A* which causes it to change its rate of motion relative to *B* by an amount *Q*, will of necessity cause *B* to change its rate of motion relative to *A* by an amount *Q*, since it is by all physicists agreed that the *mutual* accelerations of material bodies are necessarily the same. This force may be of any kind we please. It may be applied to both bodies equally, as by a spring attached to and stretched between them, or it may be applied to either independently of the other. But the acceleration of a body under the influence of a given force is the measure of its inertial mass, and as this acceleration *relative to each other* is the same for *A* and *B*, their inertial masses must be the same, if measured by this relative acceleration, even though the gravitational mass of *B* is a million times that of *A*. And this proof obviously applies to any two bodies irrespective of their gravitational mass. The bearing of this bizarre consequence of denying an absolute frame of reference will become plainer in Section 23, where it will be shown that the facts of inertia are critical in invalidating the assumptions of relativity, and confirming those of the radiation theory.

That theory, indeed, ignores neither the similarity between inertia and gravitation noted by Einstein, nor the dissimilarities unnoted by him. It is in complete harmony with both. This has been shown in the discussion of the gravitational and inertial behavior of bodies to be found in Chapter V, and will become clearer by comparing the power of the two theories to "explain" that behavior. Let us, therefore, direct attention to that subject.

Section 22. What is the explanation of the inertial and gravitational behavior of bodies?

It will be noted that in the quotation from Eddington, on page 230, it is stated that the identification of inertia and gravitation "explains" why weight is always proportional to inertia. This sounds very much as if the identification of the two properties explained their identification, rather a mysterious method of explanation and one worth examining.

The ability of the definitions of relativity to explain and predict has puzzled many physicists, since the premises do not appear to rest upon a sufficient observational basis to support the conclusions. We shall find, indeed, in Section 25 that the power of the general "theory" to explain *anything* is denied by some of the ablest advocates thereof. Reference to the distinction discussed in Chapter II between dimensional and non-dimensional "explanation" should serve to clear up this puzzling situation, but we may throw further light upon the matter perhaps by directing attention to another distinction.

By the explanation of a fact is meant something other than the fact itself, expressible in a proposition or propositions, from which the fact may be, or might have been, inferred. If we observe a person fall on the sidewalk, and on close inspection discover a banana-peel on the walk in the immediate vicinity, we are able to propose a plausible "explanation" of the fact of his fall. That is, from the hypothesis that he trod upon the slippery peel, we are able, from our knowledge about friction, banana-peels, gravitation, human equilibrium, etc., to infer the fall, and hence "explain" it. This is a real inductive explanation. It does not involve certainty (as deduction does) and

requires knowledge (about friction, etc.) other than the fact to be explained, and a knowledge of something more than the meaning of words.

But there is another kind of explanation often confused with this. It may be called verbal explanation to distinguish it from the real kind illustrated above. If, for example, we observe a familiar article of furniture having four legs, a seat and a back, we are able, from our knowledge of language alone, to infer that the word which will customarily be applied to it will be the word "chair," and hence to "explain" why it is (or is called) a chair. Moreover, we are likely to preface our explanation by the word "because" just as we would were the explanation a real one. The article is a chair "because" it conforms to the definition of a chair, just as the person fell down "because" he trod upon a slippery banana-peel. But in this instance of the chair the "because" implies only verbal knowledge. It is an explanation of a fact, to be sure, but it is only the fact that a given thing is called by a given name. It is not a fact inherent in the properties of substances, or the operations of nature, but a fact about the conventional symbolism adopted arbitrarily by human beings. In Germany, for instance, the inference would be false and would supply no explanation, merely because the word "chair" is not the word which German people happen to apply to such an article of furniture. The banana-peel explanation, however, would apply as well in Germany as anywhere else.

Now it often happens that a verbal explanation is mistaken for a real one, and hence the delusion arises that information has been received about characteristics or laws of nature, when the information is only about the usage of words or other symbols. In short, verbal knowl-

edge is mistaken for real knowledge. Thus the fact is observed that material bodies tend to fall toward the centre of the earth. This fact is given the name of gravitation. And then we "explain" the fact that bodies tend to fall toward the centre of the earth by pointing out that it is due to their "gravitation" or tendency to gravitate. Similarly, it is observed that certain kinds of drugs tend to put people to sleep. Drugs having this tendency are called soporific, or possessing the characteristic of soporification. Then we "explain" why a given drug puts people to sleep by our ability to attribute to it the characteristic of soporification. Thus we assume to explain a fact by the fact itself, an assumption which is greatly facilitated if the fact has received a definite name. As Preston remarks:

> "The introduction of a new word is very satisfying to a certain class of mind, and often stops further inquiry. There are many who are quite satisfied that a phenomenon is explained when it has received a name."[54]

We are, I believe, entitled to assume that the relativists are seeking a real or material explanation of the familiar fact of the proportionality of inertia and gravitation, first noted by Galileo. And if this is the case it is plain that they cannot find what they are seeking by citing the fact itself, or by showing that it is something to which the name given that fact is applicable. Yet the attempt is continually made to do this, apparently because the distinction between verbal and real explanation is not clearly apprehended. We may illustrate this by quoting more at length the passage from Eddington, referred to on page 230. It is as follows:

[54]Preston, Thomas, *The Theory of Heat,* pp. 76, 77.

"Whether the natural track is straight or curved, whether the motion is uniform or changing, a cause is in any case required. This cause is in all cases the combined inertia-gravitation. To have given it a name does not excuse us from attempting an explanation of it in due time. Meanwhile this identification of inertia and gravitation as arbitrary components of one property explains why weight is always proportional to inertia. This experimental fact verified to a very high degree of accuracy would otherwise have to be regarded as a remarkable law of nature."[55]

Note that Eddington in this passage disclaims, at least by implication, any power in the name "inertia-gravitation" to explain anything. Yet in the very next sentence he "explains" the proportionality of weight and inertia by means of it. In other words, the fact is (meanwhile?) explained by the fact itself when once said fact has received a name. In a similar manner we may explain why soporific drugs put people to sleep. It is obviously by virtue of their soporification. Moreover, we can apparently cause laws of nature to cease from being laws by the process of naming them. Thus the application of the name "inertia-gravitation" causes the remarkable law discovered by Galileo to be no longer "a remarkable law of nature." It is somewhat doubtful to be sure whether the name removes the lawfulness or the remarkableness from Galileo's discovery, but either accomplishment shows "remarkable" power in a name. However, this is not the only doubtful point in Eddington's "point of view." We shall point out presently that he denies that Einstein has achieved an explanation of gravitation at all, despite the fact that the nineteenth section of Einstein's book *Relativity* purports to give a *solution* of the problem of gravitation on the same basis as

[55]Eddington, A. S., *Space Time and Gravitation*, p. 137.

Eddington's "explanation" quoted above, and hence is given the appropriate heading: "The Solution of the Problem of Gravitation on the Basis of the General Principle of Relativity."

For confirmation of the claim that the explanation of gravitation by means of such mathematical fictions as "inertia-gravitation" or "curvature of space-time" is of a purely verbal and circular character—a mere truism—we may turn to another volume by Eddington, where the following illuminating passage is to be found:

> "The statement that space-time round the earth is 'curved'—that is to say, that it is not of the kind which admits Galilean coordinates—is not an hypothesis; it is an equivalent expression of the observed fact that an irreducible field of force is present, having regard to the Newtonian definition of force. It is this fact of observation which demands the introduction of non-Galilean space-time and non-Euclidean space into the theory."[56]

Thus to say that space-time is "curved" is merely to express the observed fact that bodies tend to gravitate toward one another, and specifically that the bodies around us tend to gravitate toward the earth. It is "an equivalent expression," *i. e.*, only another way of stating "this fact of observation." Yet when the relativists are asked why bodies tend to gravitate as they are observed to do, they tell us that it is *because* space-time is curved. In short, they gravitate because they gravitate. And this constitutes "The Solution of the Problem of Gravitation on the Basis of the General Principle of Relativity." No wonder the authorities quoted in Section 25 maintain that the general theory of relativity is incapable of explaining anything.

[56]Eddington, A. S., *The Mathematical Theory of Relativity*, p. 39.

This reduction of the explanations of relativity to a set of truisms originates in the attempt, described in the introduction to this chapter, to reduce physics to geometry. For geometry is a purely deductive science, founded on the three laws of thought, and by their means deriving its propositions from definitions and axioms—both of which are truisms. The relativists, being mathematicians, naturally follow the methods of their science and attempt to convert an inductive, experimental science, like physics, into a deductive one. They might as well attempt to do the same thing to meteorology and predict the weather from a set of equations founded on definitions, or redefinitions only. Inductive sciences are founded on the laws of uniformity of nature and causation, and hence cannot be rendered exclusively deductive. Strictly mathematical truths are confined to ideal systems which only approximate real ones. A Euclidean "line" for example—a length with neither breadth nor thickness—is not to be observed in nature, though various degrees of approximation to it are. Thus in the effort to convert an inductive science into a deductive one, the mathematician not only causes probabilities to pose as certainties, but in identifying his exact laws with the inexact ones of the physicist, never achieves a perfect, but at best an approximate, identification. The difference between the inductive method of the physicist and the deductive one of the mathematician is suggestively expressed by Bolton, as follows:

"Physical truth and mathematical truth are different things. The definitions and postulates of physics have to agree with nature, those of mathematics need only agree with one another. The truth of Euclid would be unaffected though such things as squares, straight lines, right angles, and the like never existed. The chances are probably mil-

lions to one against the existence of an exact square according to Euclid's definition, and it is quite certain that no one is gifted with faculties refined enough to recognize it if it did exist. As a rule, mathematical definitions agree with natural conditions more or less, since they are generally suggested by them, but it is not necessary that they should, and the mathematician, if he is a pure mathematician and not a physicist, is not concerned."[57]

Moreover, by their attempt to substitute redefinition or re-naming for experiment as a means of advancing knowledge, as by substituting the name "dimension" for "variable," the relativists have only succeeded in achieving the verbal semblance of a geometrical explanation. For, as pointed out on page 189, beyond the first three "dimensions," there is nothing geometrical about their non-Euclidean structures except the sound and spelling of the words. Thus, as Russell points out (page 10), a relativity "explanation" turns out to be a mere truism, or, as Heyl calls it, "a hollow mathematical shell, with no real content."[58] And Eddington, baffled by its tautological character, exclaims: "The whole thing is a vicious circle. The law of gravitation is—a put-up job."[59] The circle of course is not vicious. It is only confusing. But not more so than other dimensional circles. It is in truth one of the most crucial and valuable cosmic clues ever discovered, and when deciphered by the appropriate Rosetta Stones, supplies the missing link in the evidence that matter is radiational in nature. For if it is not, why are all its motions accompanied by Doppler-displacements? It is true the relativity explanations are circular, truistic, question-begging and upside down; hence naturally bewilder-

[57]Bolton, L., *An Introduction to the Theory of Relativity*, pp. 13, 14.
[58]Heyl, P. R., *The Common Sense of the Theory of Relativity*, p. 36.
[59]Eddington, A. S., *The Nature of the Physical World*, p. 143.

ing to those who do not recognize their dimensional character; but he who denies their significance is mistaken.

Confusion of verbal with real explanation, however, has not prevented the relativists from attempting an explanation of the latter kind. They have in fact advanced a real inductive hypothesis to provide the solution of a problem which "on the basis of the general principle of relativity" had already been provided by a re-naming process. The necessity for this arose because among the facts to be explained were included more than those furnished by the laws of falling bodies. Among other facts calling for explanation were those characterized by the tendency of bodies to impart their state of motion, as illustrated by the laws of impact, the tendency of vehicles which attempt to turn too sharp a corner to overturn, the jerking of railway trains whose condition of uniform motion is suddenly changed, etc., etc. And in particular the facts of rotation, such as those furnished by gyroscopes, the flattening of the Poles of the earth, the 12-hour tidal interval, the direction of rotation of cyclonic storms, not to mention the behavior of Foucault's pendulum. It is unnecessary to enumerate them all. They are, in general, phenomena associated with inertia.

To illustrate the kind of situation faced by the theory of relativity with regard to inertia, we may for the present restrict attention to the phenomena connected with Foucault's pendulum, which, as already noted, maintains its axis of vibration in a fixed direction in space, irrespective of the motion of the earth. Now it is a fundamental postulate of relativity that all motion is relative to material bodies, and there is no such thing as a unique direction in space except as it may be determined by such bodies. But the motion of Foucault's pendulum cannot be determined

by the position or motion of the earth. Neither can it be determined by the sun or any member of the solar system, since its direction of swing is uninfluenced by the position or motion of such bodies. Neither is there any other particular body or group of bodies known to which its behavior may be attributed. What material bodies then can determine its motion? There appears to be only one answer. It must be the fixed stars, since there are no other material bodies relative to which its vibrations maintain a determinate direction. Reasoning of this kind appears to be the origin of Einstein's theory that the inertia of bodies is due to the sum total of matter in the universe—for the behavior of Foucault's pendulum is obviously due to inertia. But as inertia and gravitation are identical according to the theory of relativity, gravitation also must be due to the same cause. This hypothesis is an attempt at a real, as distinguished from a verbal, explanation of the phenomena of inertia and gravitation. It attributes the effect to a physical cause instead of to a mathematical fiction. And there is no denying that such a cause might conceivably produce such effects, since, as Hume long ago pointed out, the relation between cause and effect cannot, like the laws of mathematics, be inferred from the laws of thought, but can only be discovered empirically. In condensed form Einstein's hypothesis may be expressed thus: Premise: The amount, distribution and motion of the matter in the universe is so and so. Conclusion: Therefore, the motion and tendency to motion of material bodies on the earth (and elsewhere) under the influence exerted by this amount, distribution and motion, is what we find it to be. As thus stated it is clear that the conclusion does not follow from the premise. Hence before this hypothesis can be accepted as an explanation, the missing premises must

be supplied by an appeal to the evidence. The plausibility of the explanation must then be judged by its consistency with the sum total thereof. At least this is the test which is generally applied to hypothetical explanations, and there seems no good reason why a relativity explanation should not be subject to it.

The relativists, to be sure, do not state the hypothesis in this plain manner, but express it in terms of "space-time" and the "curvature" thereof, caused by, or perhaps constituting, matter. This curvature (sometimes described locally as a "wrinkling" or "puckering") of space-time, apparently sets up some condition or other called a "gravitational field," or "metrical field" or "inertial frame." These at least are some of the names used, apparently referring to the same condition of space or space-time. And this "field" or "frame" determines certain "lines" called geodesics, which have at least an analogical resemblance to Euclidean "straight lines." And these lines we are to understand constitute paths of least resistance for material bodies and thus determine their motion, though what is "resisting" their motion along other lines is not apparent. There is much variation in the language by which this non-Euclidean "space" or "continuum" is referred to. And hence the hypothesis becomes very mysterious and difficult to grasp, so difficult indeed that, as we have seen, the relativists themselves are unable to distinguish between their verbal and their real attempt at explanation, and even deny that there is anything in the nature of explanation to be found in the theory of relativity—which is true enough if we except dimensional explanations. However, we shall make no further attempt at this point to express the meaning or position of the relativists, but to avoid misunderstanding—if it is possible

to avoid it—will let them speak for themselves. In noting the significance of the following extracts, the reader should not forget the identification of gravitation and inertia by the relativists, so that, presumably, when one is referred to the other is referred to also. The following expressions are typical:

"It has been seen that the gravitational field round a body involves a kind of curvature of space-time, and accordingly round each particle there is a minute pucker. . . .

"The track of a particle of matter is thus determined by the interaction of the minute gravitational field, which surrounds and, so far as we know, constitutes it, with the general space-time of the region."[60]

"It [the principle of relativity] postulates no particular mechanism of nature, *and no particular view as to the meaning of time and space,* though it may suggest theories on the subject. The only question is whether it is experimentally true or not."[61]*

[60]Eddington, A. S., *Space Time and Gravitation,* p. 138.

[61]*Ibid.*, p. 28.

*This statement of Eddington probably compresses more kinds of misunderstanding into thirty-eight words than can be found similarly compressed elsewhere in the literature of relativity—which is saying a good deal. In the first place, there are no such things as theories about the "meaning" of time and space, for, as Eddington himself correctly says, in the quotation on page 11, these words are defined as ideal magnitudes having the properties deliberately assigned to them. Their meaning is stipulated by definition. There can be no theorizing about it. To attempt such a thing would be as sensible as for a mathematician to stipulate that x shall stand for (mean) the unknown quantity in his problem, and then to theorize as to whether or not x means the unknown quantity. Indeed, as pointed out in Chapter I, Einstein is very careful to insist that his statements, referred to in that chapter, about "simultaneity," "time" and "length" do not express hypotheses, but *stipulations of his own freewill* (postulates) about their *meanings.* In the second place, Einstein, far from postulating "no particular view about the meaning of time and space" postulates very particular "views" about their meanings. Indeed the whole predicting power of his theory is founded on the new meanings thus carefully postulated and deliberately assigned, meanings more particular and specific than they had ever received before. There would in fact

"Matter does not cause the curvature of space-time; it *is* the curvature."[62]

"We have seen that wherever matter exists space-time has a curvature."[63]

"The phenomena cited above [the falling of glasses in a dining car rounding a curve, and bursting of rapidly rotating fly-wheels] are partly* an effect of the fixed stars *relative to which* the rotation takes place."[64]

*Weyl explains the word "partly" in a note, not relevant to quote here.

"But somehow . . . Einstein inclines to the belief that every particle owes its whole inertia to all the remaining matter in the universe."[65]

"The inertial effects which we observe in bodies are to be traced back to the influence which is exerted upon them by other bodies. (This influence is, of course, in accord-

be no such thing as a theory of relativity in the absence of these particular meanings. In the third place, how could these words, or indeed any words, be of any service to science if they had no particular meanings? They would stand for nothing, and hence would not fulfil the only useful function of symbols. They would be of no more use than any other chance combination of letters, such as *djnf* or *zbokf*. If words having no particular meaning can be of service to science, let Eddington try these two next time he has use for such things. They will do as well as any others, since they have no particular meaning. In the fourth place, the expression of the theory (principle) of relativity involves the terms "time" and "space," and how would it be possible to ascertain whether "it is experimentally true or not" if the terms in which it is expressed have no particular meaning? How can anyone tell whether a proposition is true or not if the words in which it is expressed are without particular meaning? It would be like trying to discover whether the statement that "All *djnf* are *zbokf*" is true or not. These few words of Eddington illustrate as few other passages can, what happens to a physicist when he turns metaphysicist.

[62]Eddington, *Report on the Relativity Theory of Gravitation*, p. xi.
[63]*Ibid.*, p. 84.
[64]Weyl, H., *Space—Time—Matter*, p. 221.
[65]Silberstein, L., *General Relativity and Gravitation*, p. 130.

ance with modern views, to be conceived, not as an action at a distance, but as being transmitted through a field.)"[66]

"If we assume all accelerations to be relative, then all centrifugal forces, or other inertial resistances which we observe, must depend on motion relative to other bodies; we must therefore seek the cause of these inertial resistances in the presence of these other bodies. If, for example, there were no other body present in the heavens except the earth, we could not speak of a rotation of the earth, and the earth could not be flattened at the poles. The centrifugal forces, as a consequence of which the earth's flattening comes about, must thus *owe* their existence to the action on the earth of the heavenly bodies."[67]

"We have pointed out that gravitation is an effect by which any body placed in a given position acquires an acceleration which depends upon the position and not upon the accelerated body. Thus, in a sense, we may say that gravitation is a property of space-time. . . . Some would prefer to say that the space-time considered by Einstein is not so much space-time, as space-time cum gravitation."[68]

"The mutual attraction between very small spheres of lead in a terrestrial laboratory must . . . depend on the girth and mass of the whole universe, so that these two cosmological constants must manifest themselves in the intensity of the attraction."[69]

"Like gravitational forces, so all *inertial forces,* being characteristic of the behavior of a moving body at a particular point in space and at a definite time, are not a consequence of absolute accelerations, but are *determined by the space-time distribution of matter in the universe.*"[70]

[66]Schlick, M., *Space and Time in Contemporary Physics,* p. 43.
[67]*Ibid.,* pp. 41, 42.
[68]Jeffery, R. B., *Relativity for Physics Students,* p. 138.
[69]Haas, A., *The New Physics,* p. 150. [70]*Ibid.,* p. 135.

It has already been pointed out that the hypothesis of the influence of the total matter in the universe is a possible—we will not say a plausible—explanation of the facts of gravitation and inertia, and if it is an explanation at all, it is a real, not a verbal, one. Yet the relativists seem to be in much doubt about the matter themselves. They sometimes seem uncertain whether Einstein has proposed any hypothesis, and if he has, whether it constitutes a possible explanation or some kind of non-explanation. Thus Bridgman remarks:

"Perhaps some day we shall become so familiar with the idea of a non-Euclidean space that we shall *explain* (instead of describe) the gravitational attraction of a stone by the earth in terms of a space-time curvature imposed by all the rest of the matter in the universe."[71]

and Eddington provides us with this statement; which is rather mystifying in view of the quotation on page 243:

"Einstein's main achievement is a new law, not a new explanation, of gravitation."[72]

In another place he amplifies this denial of Einstein's claim, as follows:

"In this discussion of the law of gravitation, we have not sought, and we have not reached, any ultimate explanation of its cause. A certain connection between the gravitational field and the measurement of space has been postulated, but this throws light rather on the nature of our measurements than on gravitation itself. The relativity theory is indifferent to hypotheses as to the nature of gravitation, just as it is indifferent to hypotheses as to

[71]Bridgman, P. W., *The Logic of Modern Physics,* p. 38.
[72]Eddington, A. S., "The Theory of Relativity and Its Influence on Scientific Thought." Romanes Lecture. p. 28.

matter and light. We do not in these days seek to explain the behaviour of natural forces in terms of a mechanical model having the familiar characteristics of matter in bulk; we have to accept some mathematical expression as an axiomatic property which cannot be further analysed. But I do not think we have reached this stage in the case of gravitation."[73]

In these extracts the implication is particularly plain that the theory of relativity suggests no explanation of gravitation or hypothesis about it. Yet what is the attribution of the inertial and gravitational behavior of bodies to the influence of all the matter in the universe but an hypothesis put forward as an explanation? Perhaps Bridgman and Eddington think it is too far fetched to warrant such a name. Yet evidently other relativists, including Einstein, do not agree with them. At any rate, it is no more far fetched than the old hypothesis that the movements of the planets are attributable to the guidance of spirits. Moreover, despite the fact that Eddington spurns any attempt to explain the behavior of material bodies "in terms of a material model" he seems to regard its explanation in terms of a "mechanism" to be both desirable and perhaps possible, for he says:

"It may not be an unattainable hope that some day a clearer knowledge of the processes of gravitation may be reached; and the extreme generality and detachment of the relativity theory may be illuminated by the particular study of a precise mechanism."[74]

On another page Eddington recognizes the existence of the total matter theory, but raises the question of its conceivability, thus:

[73]Eddington, A. S., *Report on the Relativity Theory of Gravitation*, p. 91.
[74]*Ibid.*, p. 91.

"It [Einstein's hypothesis about the finiteness of space, suggested by the total matter theory] is . . . open to the serious criticism that the law of gravitation is made to involve a constant λ, which depends on the total amount of matter in the universe. . . . This seems scarcely conceivable; and it looks as though the solution involves a very artificial adjustment."[75]

Whether the radiation theory gives us a clue to the "precise mechanism" which Eddington hopes for, is something which its agreement with the sum total of the facts must determine, but at any rate it provides a real, if hypothetical, explanation, and attributes the inertial and gravitational behavior of bodies to something less mystical than the influence of the heavenly bodies, an explanation which is not only "very artificial," but suggests the revival of astrology.

Another comparison between the total matter theory and the radiation theory is worth noting at this point. The former is incapable of verification. Mill's canons of induction embody the rules whereby causal may be distinguished from non-causal associations in nature, but none of them can be applied to Einstein's hypothesis since there seems no known way of varying the relation of material bodies to the sum total of matter in the universe. Even if we assume that moving them about on the earth's surface or observing their motions in the heavens constitutes such a variation, no confirmation of the hypothesis is forthcoming. In fact, the hypothesis is equivalent to the old theories of the will of God, or pre-established harmony. No imaginable behavior of material bodies can either confirm or refute it. There is no testing such hypotheses, and they are as well—and as ill—adapted to explain the yellowness of gold or the wetness of water as

[75] *Ibid.*, p. 87.

the inertial and gravitational behavior of bodies. Any one of the three here mentioned *may* be the true explanation—and one is about as plausible as another—but there is no way by which any process of reason can distinguish between them.

How comes it then that such an hypothesis has been seriously proposed? The answer is not far to seek. It is because it is the only hypothesis, likely to commend itself to a physicist, which is left when once the theory that all motion is relative to material bodies is accepted. The relativists having definitely accepted this theory, therefore, are forced to accept its consequences. Hence the "total matter in the universe" theory. In short, for the relativist, it is a Hobson's choice. In view of the inertial behavior of bodies, including their rotational behavior, it is the only alternative which is not obviously arbitrary. But being as unverifiable, it is as useless, as the theory of pre-established harmony.

The radiation theory, on the other hand, is subject to no such criticism. The experiments described in the last section and many others of like character show, if Mill's canons of induction are of any value, that the gravitational behavior of bodies is causally connected with the size and proximity of other bodies, whereas the inertial behavior is not, which is what the radiation theory predicts. This agreement with the facts, to be sure, does not prove the radiation theory to be true, because some other theory may be proposable which would predict them also. But as between the two theories under comparison, the decision of reason is not doubtful. The radiation theory provides an explanation of the inertial and gravitational behavior of bodies, whereas the total matter theory can neither explain nor predict anything. The radiation theory

is therefore confirmed, so far as the facts here under consideration can confirm it, whereas the total matter theory is not even confirmable.

Section 23. Is the acceleration of material bodies relative exclusively to other material bodies?

That the answer to this question by the relativists is in the affirmative may be discovered, not only from their denial of any non-material frame (ether) to which acceleration might be relative, but by reference to their own explicit statements. Indeed to deny that motion can be absolute* and yet admit that change of motion can be, would involve a contradiction, since the absolute frame of reference required for absolute change of motion would provide a frame for absolute motion also. Furthermore, the statements cited in Section 18 are not confined to uniform motion, and if more explicit denials of absolute acceleration are desirable, they may be cited, as follows:

"We feel tempted to deny the existence of absolute velocities, but to assume the existence of *absolute accelerations and rotations.* However, such ideas would in the long run signify a return to the prejudices surmounted by the principle of relativity, to the Newtonian conceptions of an absolute space and an absolute time. We can understand that theoretical physicists and in particular the creator of the theory of relativity could not permanently reconcile themselves to the idea of such a partial and inherently contradictory relativity."[76]

*It may here be premised that by an absolute frame is meant a non-material frame or "ether." The evidence to be presented in this section shows that there is at least one such frame, but does not show that there may not be more than one. This much, however, is sufficient to show that the velocities and changes of velocity of material bodies are relative to something beside other material bodies.

[76]Haas, A., *The New Physics,* p. 133.

"The recognition that there is no state of motion whatever which is physically privileged—that is, that not only velocity but also acceleration are without absolute significance—forms the starting point of the [general relativity] theory."[77]

A main objective of the Michelson-Morley experiment was the discovery of an absolute frame of reference by detection of the motion of the earth relative thereto. It is generally agreed that the experiment did not achieve the objective sought. Discovery of an absolute frame by detection of absolute change of motion (acceleration), however, is a different matter; and it is the purpose of this section to present reasons for believing that, contrary to the basic assumption of relativity, such absolute change of motion is detectable by very simple inertial experiments, of which the following is an example:

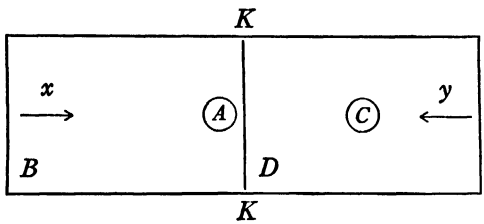
In Fig. 6, *E—E* is the smooth, horizontal surface of a table. *B* and *D* are blocks (pads) of paper of the same size lying upon it. *A* and *C* are coins of the same size resting upon *B* and *D* respectively. To prove the existence of an absolute or unique frame of reference in the universe, place the blocks in the first position shown in Fig. 6, place the coins *A* and *C* in the centre of the blocks as shown, attach the block *D* to the table in any suitable manner, as by a clamp or by holding it down firmly with the hand, and move block *B* in the direction of the arrow *x* until the edges of the two blocks collide, as at *KK* in the second position shown. *B* should be grasped lightly and brought to a velocity of about three feet a second at the time of its collision with *D*. It should also be started from rest rather gently, so that *A* will not move from the centre of *B* previous to the collision with *D*. Inspecting the blocks

[77]Einstein, A., New York *Times*, Feb. 3, 1929.

Fig. 6

First position—before collision.

E Second position—after collision. *E*



and coins after the collision, it will be found that *A* has moved relative to *B* a short distance in the direction of the arrow *x*, as shown in the second position, whereas *C* has not moved relative to *D* in the direction of the arrow *y*, or in any other direction. No matter how often the experiment is repeated the unsymmetrical movements thus noted will be found to occur. These facts refute the assumptions of relativity about exclusively relative motions and accelerations by leading to the discovery of a unique frame of reference in the universe. Let us call this the block and coin experiment. The method of inferring absolute acceleration from it follows:

There is *some* cause for the motion of *A* relative to *B*. By Mill's second canon the cause is shown to be the sudden retardation (negative acceleration) of *B* on impact with *D*, because the motion occurs immediately after the

impact and at no other time. But the cause cannot be the retardation of B relative to D *exclusively*, since the retardation of D relative to B is equal and opposite to the retardation of B relative to D. That is, the *relative* (mutual) retardations are alike. Hence if these two are the *only* retardations involved, any cause set in operation thereby, resulting in the motion of A relative to B will result in a symmetrical motion of C relative to D. But no such symmetrical motion occurs. The retardation of B on impact with D, therefore, is relative to *something* to which the retardation of D on impact with B is not relative, for the retardation of a body relative to *nothing* is impossible.

This reasoning may be condensed into the following hypothetical syllogism:

If the retardations of the blocks on impact are alike, their effects on the movements of the coins will be alike.

But their effects on the movements of the coins are not alike.

Therefore the retardations of the blocks on impact are not alike.

In this syllogism, the first premise is a familiar corollary of the law of causation, the second a record of observation, and the conclusion a proposition in conflict with the fundamental assumption of relativity. It is in conflict therewith because only *two* material bodies are involved, namely, B and D (A and C are only tell-tales). Inequality of acceleration between them, therefore, is impossible. That is, the retardation of the blocks on impact must, according to this assumption, be alike, because the minimum number of frames of reference admitting of *un*likeness of acceleration is *three*.

The non-equivalence of acceleration shown by the block

and coin experiment follows from assumptions regarding the ether to be found in Chapter V, and may be explained thus:

On accelerating the block *B* in the direction *x*, *A* is caused to share the increased motion by virtue of the friction between *A* and *B*, but on collision with *D*, the (negative) acceleration of *B* is so rapid that the tendency of *A* to retain its rate of motion relative to the ether (its inertia) is great enough to overcome friction with *B*, and it slides in the direction *x* during the time that it takes the friction between *A* and *B* to transform its kinetic energy into heat. The less the friction the longer time (and length of slide) it will take. This explains why *A* moves relative to *B* following the impact of *B* with *D*. Now why does *C* *not* move relative to *D* in the direction *y*, symmetrically with the movement of *A* relative to *B?* This, of course, is the question that puts the relativist in the inertial dilemma. But it is no dilemma to the non-relativist. As he attributes the inertial behavior of bodies to their reactions with a unique frame of reference, he explains the absence of motion of *C* relative to *D* by simply pointing out that on the impact of *B* with *D*, *D* is not appreciably accelerated relative to the ether, because it is attached to a large body (the table) and such a small force as that imposed by the collision between *B* and *D* cannot change its rate of motion relative thereto with sufficient suddenness to overcome the friction between *C* and *D*. The change of motion of the table relative to the ether caused by the impact, indeed, would be inappreciable, even if it rested on a frictionless surface. If the behavior of the coins in the experiment is due to the causes to which the non-relativist attributes it then, *C* ought not to move relative to *D*, and observation shows that it does not. It is obvious that various modifi-

cations of the experiment may be devised. By detaching D from the table, for instance, the movement of the two coins on impact of B with D can be made symmetrical within the limits of accuracy of so rough an experiment. And by varying the relative sizes of the blocks, various degrees of asymmetry between the movements of the coins can be caused, *the greater relative movement thereof always being associated with the smaller (lighter) block.* Moreover, the same results will be obtained in a railway train moving with any uniform velocity in any direction. Thus the non-relativist explanation may be confirmed to any degree required.

The non-relativist agrees with the relativist that D is no more a unique frame of reference than B. The fact that D remains stationary relative to the table, and therefore to the earth on which the table stands, does not make it a unique frame. He also agrees with the relativist that the sun or Sirius is no more a unique frame than the earth or B. He would go even further, and stand firm where some inconsistent relativists are inclined to wabble, and assert that the fixed stars, or the total aggregate of material bodies in the universe, do not constitute a unique frame of reference. Any one of these frames is as fundamental as any other, and the only choice between them is one of convenience. He is in complete agreement with Eddington in contending that:

> "Once he [an observer] gives up the naïve assumption that his own frame is the one and only right frame the question arises, Which then of the innumerable other frames is right? There is no answer, and so far as we can see no possibility of an answer."[78]

[78]Eddington, A. S., *The Nature of the Physical World,* p. 15.

It is in fact the very impossibility of answering this question, as applied to any material frame of reference, that refutes the contention of relativity. The really unique frame is not visible through any telescope or perceptible by human senses. It is, however, all about us, a medium pervading all matter, including the earth, the table, the blocks *B* and *D* and the coins *A* and *C*, and capable of interchanging energy with them.

The explanation of inertia provided by the radiation theory also makes evident why the earth, for ordinary human experiments, can be safely used as an absolute frame of reference. It is because, in the first place, the cosmic causes which determine the motion and change of motion of the earth act upon all bodies used in experiments in the same manner as upon the earth itself, or that part of the earth immediately adjacent to the experiment. Even tidal forces thus act. Hence the accelerations to which the earth is subject are not detectable by bodies upon it, because they are not communicated to the bodies through the surface on which the bodies rest (as the acceleration of block *B* is communicated to coin *A*), but are communicated directly through the ether to every particle of which the bodies are composed. If this were not the case, people and objects on the earth would be subject to differential movements incident to the acceleration of the earth's orbital motion, similar to those caused to passengers in a train when the train speeds up or slows down. In the second place, the mass of the earth is so great that ordinary human experiments cannot apply forces to it sufficient to cause any appreciable change of its motion relative to the ether. Thus it affords a "purchase" on the ether, so to speak, of enormous magnitude, so far as humanly directed forces are concerned, and hence can act as

a reference system as stable and absolute as the ether itself.

The result of the block and coin experiment being an observed fact, and as such calling for explanation, we may next inquire how the relativist explains it. And at the outset it may be noted that the non-relativist explanation is not available to the relativist. The latter cannot claim that the unsymmetrical behavior of the coins is due to the fact that a body containing a large amount of matter is more reluctant to change its velocity than one containing a small amount, since the question will at once arise: "Velocity relative to what?" And if a unique frame of reference is rejected, this question is unanswerable, because the motions and accelerations of any two material bodies are strictly relative and equal in magnitude to *each other.* As the block B is just as much and just as little a unique frame of reference as block D, or table E, or the earth itself—and no one denies this—how are we going to answer the question "Relative to what?" in any non-arbitrary manner if we deny the existence of any frame of reference other than these and their like. Which frame shall we select? And echo (like Eddington) answers—which? The truth is that, except for a few special cases, as when two bodies of equal mass collide, all inertial phenomena involving change of motion, are inconsistent with the fundamental assumption of relativity concerning acceleration. And as uniform motion is but the limit approached by non-uniform, as the force applied indefinitely diminishes, it needs no elaborate argument to show that refutation of the assumption that there is no such thing as absolute acceleration involves refutation of the assumption that there is no such thing as absolute motion.

Few, if any, relativists have noticed the critical bearing of the principle of the block and coin experiment on the philosophy of relativity. At least I have found none that clearly recognize it. In pursuing recondite mathematical investigations they have overlooked the obvious. Some, however, have sensed it sufficiently to recognize that there is something about the inertial behavior of bodies which it is difficult for the assumptions of relativity to explain, and have engaged in various rationalizations to escape the difficulty. But I have never found a relativist writer who has faced the dilemma in the simple form presented by the block and coin experiment, and I have searched the works of many. In this search, nevertheless, I have uncovered three attempts to meet the difficulty raised by the inertial behavior of bodies, and as they put the relativists definitely on record in the matter of explanation, it will be of interest to present them. It is significant that none of them embody the non-relativist explanation.

First, let us see how Einstein meets the inertial dilemma. In *Relativity*, Section 18, he observes that people in a railway car become conscious of a jerk when the brakes are suddenly applied, and are thrown forward relative to the car (as *A* is thrown forward relative to *B* when *B* collides with *D*). And he remarks: "Because of this, we feel compelled at the present juncture to grant a kind of absolute physical reality to non-uniform motion in opposition to the general principle of relativity" (page 62). In Section 20, however, he suggests the analogy of the man in the chest, already noted on page 230 of this volume, and from it draws the conclusion that "the *same* quality of a body manifests itself according to circumstances as 'inertia' or as weight (lit. 'heaviness')" (page 65). Applying this analogical reasoning to the dilemma encountered in

Section 18, he deems himself able to withdraw the grant of "absolute physical reality to non-uniform motion" made at the close thereof. His mode of ratiocination in this case is as follows:

"We can now appreciate why that argument is not convincing, which we brought forward against the general principle of relativity at the end of Section XVIII. It is certainly true that the observer in the railway carriage experiences a jerk forwards as a result of the application of the brake, and that he recognizes in this the non-uniformity of motion (retardation) of the carriage. But he is compelled by nobody to refer this jerk to a 'real' acceleration (retardation) of the carriage. He might also interpret his experience thus: 'My body of reference (the carriage) remains permanently at rest. With reference to it, however, there exists (during the period of application of the brakes) a gravitational field which is directed forwards and which is variable with respect to time. Under the influence of this field, the embankment together with the earth moves non-uniformly in such a manner that their original velocity in the backwards direction is continuously reduced" (pages 69–70).

He then closes the section and abruptly changes the subject without pausing to notice that a man on the railway embankment does *not* feel a jerk, and is *not* thrown backward relative thereto (just as C is *not* moved backward in the direction y relative to D). Had he noted this unsymmetrical behavior what would have become of his "explanation"? The only solution of the inertial dilemma he proposes is that the retardation of the carriage is not a "real" one. In short, it is an *un*real one! Raising this issue of "reality," of course, muddies the waters and switches the discussion into the metaphysical obscurity which has so long beset that issue. Digression into a dis-

cussion of the nature of the "real" would certainly lead us on a grand red herring trail away from the inertial issue, and I do not propose to follow it. But if the *real* jerk of the man in the train is caused by an *un*real retardation of the train, as Einstein suggests (and he suggests no other explanation), we are left to infer I suppose, that the *un*real jerk of the man on the embankment is caused by a *real* retardation of the embankment. At any rate, a cause of this latter retardation "exists," though its effect is a non-existent jerk. What is to be made out of this? Where is its intelligibility? Whether the real or the unreal retardation is the absolute one, or whether either is, we are not clearly informed, but whatever Einstein may mean by "real," it is at least different from "unreal." Hence he has attributed *something* to the retardation of the embankment relative to the train which he has *not* attributed to the retardation of the train relative to the embankment, and thus has denied the assumption of relativity that there is no difference between them. Furthermore, when he assumes that the carriage "remains permanently at rest," the question necessarily arises—At rest relative to what? For rest is as much a relative affair as motion. Certainly it is not at rest relative to the embankment, or to the observer who is jerked forward relative to it. To what then? Einstein does not answer this critical question, nor make any attempt to, though the whole issue depends on the answer. The statement that a body of reference is at rest, without information of what it is at rest relative to, is a statement from which no conclusion can be drawn. It yields no more information about the state of rest or motion of the body than it does about its state of temperature. It simply tells us nothing at all, and hence cannot express an explanation of anything, or any part of one.

This much must suffice to show how Einstein meets the inertial dilemma. It is by raising the issue of real versus unreal retardations.

A few moments' reflection will convince any physicist that Einstein has not approached this problem with his customary caution, for it is easy to show, in this particular case, that the cause of the retardation of the train cannot be a gravitational field. The cause is clearly a frictional reaction between the braked wheels and the track. Slippery rails often interfere with the prompt stopping of trains and frictionless rails would render brakes useless. Furthermore, when brakes are applied too forcefully the wheels lock and the friction on the rails actually causes a flat spot on the tread. To deny that the cause of the retardation of the train is a reaction between wheels and rails is to assert there can be action without reaction. But how can this frictional resistance, located at the points of contact between wheels and rails, be a gravitational field or cause one? Such fields are located in space and act on all parts of a body equally. They are not transmitted from molecule to adjacent molecule as the stresses in an elastic body are. Hence they are not transmitted as stresses from track to wheels, from wheels to axles, and from axles to trucks and car body (also back through embankment) as the force which causes the mutual retardation of train and embankment obviously is. Moreover, the retardation due to mechanical stress differs from that due to gravitation, not only in being transmitted exclusively through material media, but in being transmitted at a far lower speed. No physicist who carefully considers this example can deny that the mutual retardation involved is a phenomenon of mechanical stress, comparable to the block and coin experiment. Gravitation causes

mutual retardation in an entirely different manner. It can be confidently asserted, indeed, that if Einstein would reconsider his explanation of this phenomenon, he would withdraw it. Clearly it is a Homeric nod.

Second, let us see how Bridgman, another able advocate of relativity, meets the inertial dilemma. He approaches the problem in a different manner from that of Einstein, but it is the same old dilemma. The difficulty of the translational "jerk" noted by Einstein he does not refer to at all, but the dilemma as it presents itself in rotational phenomena forces itself upon his attention, and he has this to say about it:

> "No meaning in terms of measuring operations can be given to absolute rotary motion any more than to absolute translation, but nevertheless phenomena are obviously entirely different in different systems in relative rotary motion (phenomena of rupture for example), so that apparently there are physical phenomena by which the concept of absolute rotary motion might be given a certain physical significance."[79]

Thus he grants provisionally that "absolute rotary motion might be given a certain physical significance," and, of course, absolute motion is contrary to the assumptions of relativity. Compare this with Einstein's provisional grant of "a kind of absolute physical reality to non-uniform [translational] motion," and it will be seen that both physicists approach the inertial dilemma with a provisional recognition of the difficulty it presents to the assumptions of relativity. But as Bridgman is trying to escape the dilemma as it crops up in rotational motion, apparently unconscious that the same difficulty presents

[79]Bridgman, P. W., *The Logic of Modern Physics,* p. 180.

itself in connection with translational motion when non-uniform, he invents a means of escape which he deems suitable to his purpose, but one entirely different from that of Einstein. Inferring from the negative result of the Michelson-Morley experiment that translational motion of the earth cannot be detected by experiments confined to the earth itself, he wonders how it happens that rotational motion *can* be detected—by Foucault's pendulum, for instance. And seeking a physical explanation for the difference, he finds one in what? In the magnitude of the units in which the two kinds of motion are measured! In order that there may be no misunderstanding about this, let me quote his own words:

"A physical basis for such a difference may be found in the enormously different numerical values of translational and rotational velocities with respect to the rest of the universe attainable in practice. In describing phenomena of cosmic magnitude, we may plausibly measure the phenomena in units commensurable with the scale of the phenomena. Thus in measuring linear distances, we may perhaps choose as the unit of length the diameter of the stellar universe, and in measuring rotation, a complete reversal of direction with respect to the entire universe. This last means a change of angular orientation of 2π, the first means a length of the order of 10^5 light years. Measured in such cosmic units the angular velocities attainable in practice are incomparably greater than linear velocities. We now see that it is possible that the real state of affairs is as follows: namely, phenomena in any system are affected by motion with respect to the entire universe, whether that motion is of translation or of rotation, and the magnitude of the effect is connected with the velocity of the motion by a factor which is of the general order of unity when velocity is measured in cosmic units."[80]

id., pp. 182, 183.

This is an ingenious and intelligible, if highly speculative, method of avoiding the inertial dilemma, but the common characteristics of the inertial behavior of bodies, whether rotational or translational, are too plain to allow such a cosmic distinction to be made between their respective causes. Moreover, no such distinction between units of measurement can meet the difficulty raised by the block and coin experiment, or that suggested by Einstein, since neither of these raise the issue of angular *vs.* linear units. They are concerned with translational accelerations, and hence with linear units, exclusively. Bridgman's attempted explanation of the inertial dilemma, therefore, is irrelevant.

Third, let us see how Eddington, still another well-qualified advocate of relativity, meets the inertial dilemma. It so happens that he presents the problem for solution in essentially the same manner as in the block and coin experiment, the block *B* being replaced by a railway train, as in Einstein's example, only he does not, as Einstein did, ignore the absence of the inertial jerk to persons on the embankment. And how does he explain the phenomenon? Three guesses. Does he, like Einstein, explain it by a distinction between reality and unreality? No. Does he, like Bridgman, explain it by a distinction between angular and linear units? No. Does he, like the non-relativist, explain it by a distinction between the relative amounts of matter in the reacting systems? No. How then does he explain it? By something or other which he calls "bombardment" by "a swarm of molecules!" Here is his account of the matter:

"It will be instructive to consider an objection brought, I think, originally by Lenard. A train is passing through a station at 60 miles an hour. Since velocity is relative, it

does not matter whether we say that the train is moving at 60 miles an hour past the station or the station is moving at 60 miles an hour past the train. Now suppose, as sometimes happens in railway accidents, that this motion is brought to a standstill in a few seconds. There has been a change of velocity or acceleration—a term which includes deceleration. If acceleration is relative this may be described indifferently as an acceleration of the train (relative to the station) or an acceleration of the station (relative to the train). Why then does it injure the persons in the train and not those in the station?"[81]

Let us pause to note that Lenard's objection raises the same inertial issue as the block and coin experiment, only by a less easily analyzable example. Now observe how Eddington meets it:

"The cause of injury in the railway accident is easily traced. Something hit the train; that is to say, the train was bombarded by a swarm of molecules and the bombardment spread all the way along it. The cause is evident —gross, material, absolute—recognized by everyone, no matter what his frame of reference, as occurring in the train not the station. Besides injuring the passengers this cause also produced the relative acceleration of the train and station—an effect which might equally well have been produced by molecular bombardment of the station, though in this case it was not."[82]

Eddington, besides admitting that the cause of the injury is "absolute" has various less reasonable things to say in connection with this unique method of explaining away the inertial dilemma. But the more he says the less he explains, and the confusion can be fully realized only by a reading of the whole passage.

[81]Eddington, A. S., *The Nature of the Physical World,* p. 130.
[82]*Ibid.,* p. 131.

In considering Eddington's attempted explanation, the question arises of what molecular bombardment he can be referring to. Can it be that due to the temperature of the bodies concerned? When two bodies collide with one another, or are otherwise in contact, each is subject to such a bombardment from the molecules of the other. Is Eddington attributing the inertial behavior of material bodies and the consequent severity of railway accidents to such a temperature effect? If so, it would be rather safe to derail trains in very cold weather when the bombardments are sluggish, and at the absolute zero ($-273°$ C.) no collision at all would occur. It is safe to assume perhaps that he is not seriously proposing this kind of a bombardment. It certainly could explain nothing in any event. But what other molecular "bombardment" is there to refer to? Can any physicist suggest any other? Does he mean that when the train collides with the station the molecules of the train, or some of them, collide with some of the station? Does he mean by bombardment simply collision? If so, what he says is true enough, but hardly relevant, since no one denies the collision, to which in fact both the molecules of the station and those of the train are equal parties. Reducing Lenard's train and station example to the simpler block and coin experiment, it seems clear that whatever Eddington refers to as a "molecular bombardment" must be something which occurs at the point or surface of impact of the two blocks at *KK*. But this is an entirely symmetrical bombardment. The molecules of *B* "bombard" those of *D* as vigorously as the molecules of *D* bombard those of *B*. How then can unsymmetrical effects be produced? We are informed, to be sure, that the cause occurs "in the train not the station," yet, in some inexplicable manner it is also the cause which

"produced the relative acceleration of the train and station." But no searching can discover such an unsymmetrical bombardment—an action without any reaction. It is past finding out. Probably Eddington means by a molecular "bombardment" a mechanical stress (with accompanying strain) transmitting the force of collision from molecule to adjacent molecule throughout the train (and station). He may be trying to express the fact that the force is transmitted in this particular manner throughout the material systems affected by the collision, and not by means of a gravitational or other "field," which transmits force through space independent of any material connection. If so he is correct, and avoids the error of Einstein, noted on page 268. But he falls into another error, because he fails to recognize that mechanical stresses are forces acting equally in two (opposite) directions and not in one direction only. They are symmetrical forces whose action and reaction are equal, as required by the laws of physics. However, if Eddington's "explanation" of the inertial dilemma is correct, then Einstein's and Bridgman's must be incorrect, since neither of the latter appeal to molecular bombardment to escape the difficulty. But the fact is that neither Einstein's "reality *vs.* unreality," Bridgman's "angular *vs.* linear" unit nor Eddington's one-sided "molecular bombardment" explain anything whatever. They leave the facts of the block and coin experiment a complete mystery. The first is unintelligible, the second irrelevant, and the third incorrect. And there is no agreement between them.

Absolute motion has not as yet been detected, though Miller's repetition of the Michelson-Morley experiment, with its apparently positive results, renders this statement doubtful. Compensation effects, probably of the nature first suggested by Fitzgerald, seem to be the cause of the

failure of the Michelson-Morley experiment to prove absolute motion. But absolute *change* of motion is easily detected by the block and coin experiment and variations thereof readily proposable. One of the principal objectives of the Michelson-Morley experiment—the detection of an absolute frame of reference—is thereby achieved. But, as yet, no means of distinguishing between positive and negative acceleration relative thereto, is available. We have on page 259 referred to the change of motion of the two blocks as a retardation merely because the relative, observable, changes are negative accelerations. We have no knowledge of the absolute direction of motion of the earth relative to the ether and hence cannot distinguish between positive and negative changes in that motion. A method of doing this, however, would provide a means of detecting absolute motion. Thus far no such method has been proposed.

The result of the block and coin experiment is wholly inconsistent with the fundamental tenet of relativity regarding acceleration. Inference from it proves, as conclusively as inductive inference can prove, the existence of an absolute or unique frame of reference in the universe, though no material body or aggregate of bodies provides such a frame. The theory of relativity in denying the existence of a unique frame requires that the behavior of the coins relative to the supporting blocks shall be symmetrical. The facts show they are unsymmetrical. The experiment, therefore, is an *experimentum crucis* refuting the basic assumption of relativity.

Section 24. Do the assumptions of general relativity require a unique frame of reference in our part of the universe?

The basic idea underlying the main assumption of relativity is a very simple one and occurred to the minds of

men long before the relativity theory was suggested. It arises from the impossibility of distinguishing between the motion and rest of an isolated body in an empty and boundless space. If we assume space to be entirely empty except for a single body—say the earth—and entirely boundless, by what criterion should we be able to test whether it were at rest in space or moving? Indeed, how should we be able to assign a distinction between the meanings of the words "rest" and "motion" as applied to it? We would surely have to assign meanings having no particular connection with those ordinarily assigned, in order to make such a distinction. If some other body, such as the sun, existed in space we could observe and think of the earth as at rest or in motion relative thereto; or if space had a boundary, we could at least think of a distinction between rest and motion relative to the boundary, but in the absence of other bodies or of boundaries, the distinction disappears.

Now relativists, in common with most non-relativists, postulate a boundless space, and most relativists also postulate an empty (etherless) one. Hence the only distinction between rest and motion of a material body which is left is that relative to other material bodies, and in Sections 18 and 23 we have seen that this exclusive kind of relativity of motion, whether uniform or non-uniform, is insisted on very emphatically by Einstein and his followers. As pointed out in Section 17, those who admit the existence of an ether at once admit the possibility of absolute motion, by which is simply meant motion relative to the ether.

The difficulties encountered in the attempt to maintain this assumption have already been suggested, or at least some of them. And we have seen how the hypothesis of

the influence of the fixed stars, or more accurately, of the total amount of matter in the universe, as the cause of gravitation and inertia, has arisen in an effort to extricate the theory from these difficulties. Thus the "metrical field," or "inertial frame" due to this influence appears to provide an outlet of escape for the theory, since it affords something in space to which the rotation of the earth and the change of motion of material bodies, is able to be relative. Conflict between the special and the general theory is then avoided by the assumption that the special theory is a special case of the general, applicable only where matter and the influence of matter in causing (or constituting) a "curvature of space" is absent. But this way out of the inertial dilemma only leads the relativists into another one. For there is no known part of space not subject to the influence of matter. Hence all known space is "curved" in one degree or another, and hence in all parts of such space there is a "field" or "frame" to which material motion, both rotational and translational, may be relative. This contradicts the postulate that there is nothing in the universe to which the motion of a material body may be relative except another material body, and re-introduces an ether into physics—or at least an excellent substitute for one. At any rate it introduces as unique a frame of reference into space as the ether introduces, and at once all relativist inferences, such as those from the Michelson-Morley experiment, which postulate the absence of such a frame, are rendered invalid, since all experiments and observations of human beings are conducted in the presence of space affected by the field or fields caused by matter. The fact that the relativists give the ether another name, deny it has any resemblance to matter, and attempt to explain its presence by a far-fetched and non-confirmable hypoth-

esis, is of no consequence. The unique field or frame assumed to exist in space by the general theory, like the ether, is made manifest to us only by its effects on matter and radiation, and all the objections applicable to the old ether hypothesis apply to it—and a few more. Indeed it explains the phenomena of physics in a less natural manner than the ether hypothesis and does more violence to our experience of the ways of nature. Thus the theory of relativity, having banished the ether, is forced to bring it back again under another name and in a more fantastic form, and with the admission of absolute motion and acceleration. This contradiction between the general and special theories of relativity—at least as explanations of experimental results obtainable on the earth—has caused the relativists untold trouble, because to admit absolute motion and acceleration is fatal to their philosophy.

Perhaps the frankest admission by a relativist that there is, after all, a unique frame of reference in the universe, is that of Eddington. It is as follows:

"We have based our theory on two axioms—the restricted principle of relativity and the principle of equivalence. These taken together may be called the *physical* principle of relativity. We have justified, or explained, them by reference to a *philosophical* principle of relativity, which asserts that experience is concerned only with the relations of objects to one another and to the observer and not to the fictitious space-time framework in which we instinctively locate them. We are now led into a dilemma; we can save this philosophical principle only by undermining its practical application. The measurement of the rotation of the earth detects something of the nature of a fundamental frame of reference—at least in the part of space accessible to observation. We shall call this the 'inertial frame.' Its existence does not

necessarily contradict the philosophical principle, because it may, for instance, be determined by the general distribution of matter in the universe; that is to say, we may be detecting by our experiments relations to matter not generally recognized. But having recognized the existence of the inertial frame, the philosophical principle of relativity becomes arbitrary in its application. It cannot foretell that the Michelson-Morley experiment will fail to detect uniform motion relative to this frame; nor does it explain why the acceleration of the earth relative to this frame is irrelevant, but the rotation of the earth is important.

"The inertial-frame may be attributed (1) to unobserved world-matter, (2) to the ether, (3) to some absolute character of space-time. It is doubtful whether the discrimination between these alternatives is more than word-splitting, but they lead to rather different points of view. The last alternative seems to contradict the philosophical principle of relativity, but in the light of what has been said the physicist has no particular interest in preserving the philosophical principle."[83]

In this extract Eddington makes clear the "word-splitting" character of the distinction between the "ether" and the otherwise named unique or "fundamental" frame of reference required by the facts of physics, but this is an admission that not only the last, but all the other, alternatives (seem to) "contradict the philosophical principle of relativity,"—the non-existence of absolute motion and acceleration. For if one statement contradicts it, how can alternatives which are merely verbal or "word-splitting" variations thereof fail to contradict it? The general theory therefore succeeds only in bringing physics, by a very obscure and baffling route, back to the position which is denied in the special theory. A unique frame of

[83]Eddington, A. S., *Report on the Relativity Theory of Gravitation*, pp. 83, 84.

reference—at least in our part of the universe—is a necessity of any system of physics, and the metaphysical "non-Euclidean" language of the relativists serves not to change, but only to obscure, the fact.

That Einstein postulates a non-material something *physically real in space* to which the motion and acceleration of material bodies can be relative, may be shown from his own statements and inferences. At least he either postulates this or something so much more improbable that no physicist, who once realizes the alternatives available, can hesitate in choosing between them. To prove this, consider what Einstein says in presenting his experiment of the accelerated chest (see page 230). He tells us first that the chest is accelerated by means of a rope pulled by a being, the acceleration being relative to "another reference-body which is not being pulled by a rope," and hence is *not* accelerated. He then tells us that "the conclusion that the chest is suspended at rest in [a] gravitational field . . . violates neither reason nor known mechanical laws." In plain language this means that a gravitational field can be caused by somebody pulling on a rope. And it is entirely plain that he is right in claiming that the phenomena of falling bodies inside the chest which he describes will be observable by beings qualified to observe exactly as he describes them. Furthermore, they will be observable outside the chest, indeed *throughout space.* For if the observer in the chest ejects a body therefrom through a window, in any direction and with any velocity, and observes its subsequent behavior, he will find that, relative to him and his chest, it will behave like a falling body. Moreover, to an observer on the ejected body, his chest will behave like a falling body "falling" in the opposite direction, though neither body

will follow the inverse square law of gravitation relative to the other, since, on Einstein's assumption, the acceleration is uniform. (On other assumptions, of course, it might be non-uniform in any number of ways, according to the law of force assumed.) These conclusions follow from the same classical laws of falling bodies from which Einstein himself reasons. From which it also follows that a uniform gravitational field, in any direction, can be caused by pulling "with a constant force" on a rope! In the language of the relativists, this rope-pulling will cause *all space* to become "curved," just as an equivalent amount of matter will, except that the curvature is uniform instead of diminishing as the square of the distance; and the harder the rope is pulled, the more it curves space. A hard enough pull could curve it more than the matter in a thousand suns could do, for it is all a matter of the rapidity of the resulting acceleration. By selecting a small enough chest an ordinary man could generate a temporary field of this character. Having been guided by Einstein's reasoning thus far, let us continue to be guided by it in seeking to ascertain the character of a gravitational field. Turning then to page 195 of this volume, we shall find a quotation from Einstein ending with the sentence: "The effects of gravitation also are regarded in an analogous manner." The reader is invited to re-read this quotation, and then to consider the following statement which follows it in Einstein's book:

"The action of the earth on the stone takes place indirectly. The earth produces in its surroundings a gravitational field, which acts on the stone and produces its motion of fall."[84]

[84] *Relativity*, p. 64.

Now this gravitational field thus produced in the "surroundings," like the analogous magnetic field, is "something physically real in . . . space," and as pulling on a rope produces a gravitational field it must produce this "physically real" something in the surrounding space. And the question naturally arises: Was space absolutely empty and devoid of anything "physically real" before Einstein's being began to pull on his rope? If so, said being, by pulling on a rope, must have produced something physically real out of nothingness, and something capable of tremendous physical effects, propagated throughout space with the speed of light—at least, the relativists tell us that gravitational fields are propagated with this speed. *Now Einstein either assumes this or he does not assume it.* If he does, he assumes material acceleration to be the cause of a physical effect beyond any reasonable bounds of probability, an effect, indeed, which would make the gravitational field of a body depend, not on its mass, but on the acceleration of the particles of which it is composed—and acceleration can be caused by other things than pulling on a rope. This is obviously contrary to the most familiar facts of observation. Neither pulling on ropes, nor any other means of accelerating bodies, can alter the gravitational field of the earth. If he does not assume this, however, he must assume that a something "physically real in . . . space" existed before his being began to pull on his rope, and that the ensuing phenomena of falling bodies arose because the chest was accelerated relative to this something —and to thus assume is to assume an ether or unique frame of reference. This, in fact, is the assumption of the radiation theory, with which the phenomena observable inside (and outside) of the accelerated chest are in

entire agreement. This "inertial frame" existing throughout space, whether anyone pulls on a rope or not, is not only a cause of inertia, but is the very physical reality in space which enables an inertial field to simulate, in certain respects, a gravitational one, whenever a body (chest) is accelerated relative to it, and hence relative to any reference-body *not* accelerated relative to it. Perhaps, as Lewis contends, the assumption of an ether is a "hideous nightmare," but what kind of a nightmare is the assumption that a sufficiently strenuous being, by pulling on a rope, can produce a gravitational field throughout space greater than the gravitational field of the sun, or of many suns. It would appear to be super-hideous in a superlative degree. And yet, *Einstein, by his own reasoning, is committed to one assumption or the other.*

The answer of the radiation theory to the question discussed in this section is, of course, obvious. There is a unique frame of reference in our part of the universe, which may as well be called the "ether" as by newer, more fashionable and more confusing names, and the facts of optics, electromagnetism and gravitation powerfully reenforce those of inertia in proclaiming it.

Section 25. Can the equations of general relativity explain or predict anything?

The extracts cited in Section 22 show that at least many relativists, including Einstein himself, suppose that the theory of relativity provides a "solution" of, or "explains" gravitation and many other facts observable in nature. Thus Weyl tells us that Einstein's theory "solves the perplexing problem of gravitation and of the relativity of motion at one stroke in a manner highly satisfying to

our reason."[85] And again he says: "In virtue of Einstein's general theory of relativity, we understand in principle the nature of gravitation."[86]

It is even claimed that, by the aid of certain analogies, inspection of the equations of the general theory enable us to discover that the universe is finite, though unbounded, and even to estimate its size. There are two mutually incompatible theories about this, to be sure, one presented by Einstein, the other by DeSitter, both claiming that space is "curved," using this word in the metaphorical sense favored by the non-Euclideans. The latter, however, asserts the curvature to be "spherical," the former "cylindrical." There are various pertinent comments which might be made on these "discoveries" about the universe, especially concerning the frailty of the analogies on which they depend, but as they are frankly advanced as mere speculations which constitute no essential part of the general theory of relativity, we shall not pause to discuss them.

It is a fact, however, that the mathematics of the general theory of relativity are difficult to follow, and in this part of the theory the explanatory power of the equations, if any, is obscured from the average physicist. A few among the abler mathematicians, however, "smell a rat." They cannot help perceiving that conclusions which follow, not from the observation of nature, but merely from redefinitions, can hardly be of a character to explain or predict facts of nature—at least in the inductive manner in which other "theories" do. That the general theory cannot predict or explain the facts of the solar system in the way that Newton's theory does is quite generally admitted. As Jeans says:

[85] Weyl, H., *Space—Time—Matter,* p. 247.
[86] "Electricity and Gravitation," *Nature,* vol. 106, p. 800.

"The hypothesis of relativity alone is powerless to predict what will be the orbit of a planet."[87]

Note also the denial by Eddington, quoted on page 253, that Einstein gives any explanation of gravitation.

But there is a strong disposition among those well qualified to judge, to doubt, or even deny, the power of the general theory of relativity to explain or predict *anything.* Bridgman, for instance, informs us that:

"The explanatory aspect is completely absent from Einstein's work."[88]

And confirming this statement, we find such expressions as the following:

"The difficulty with the general theory is not so much whether the facts predicted by it are true, but whether they are really predicted and whether there may not be other facts, equally predicted, which are not true. . . . Can we admit as 'prediction' a process of reasoning in which there are gaps filled only by guesses, or at least by the selection of one out of several possible alternatives that cannot be distinguished by rigid logic? . . . So distinguished a mathematician as Painlevé maintains that Einstein's solution is only one of an infinite number all equally 'natural.' "[89]

"The much extolled Principle of General Relativity which, in Einstein's wording, requires
The general laws of Nature to be expressed by equations valid in all coördinate systems, i. e., covariant with respect to any substitutions whatever (generally covariant),

[87]Jeans, J. H., "The General Physical Theory of Relativity," *Nature,* vol. 106, p. 793.

[88]Bridgman, P. W., *The Logic of Modern Physics,* p. 165.

[89]Campbell, N. R., *Modern Electrical Theory, Supplementary Chapter; Relativity,* pp. 110, 111.

is by itself powerless either to predict or to exclude anything which has a phenomenal content. For whatever we already know or will learn to know about the ways of Nature, provided always it has some phenomenal contents (and is not a merely formal proposition), should always be expressible in a manner independent of the auxiliaries used for its description. In other words, the mere requirement of general covariance does not exclude any phenomena or any laws of Nature, but only certain ways of expressing them. It does not at all prescribe the course of Nature but the form of the laws constructed by the naturalist (mathematical physicist or astronomer) who is about to describe it. . . .

"The sameness of form of the equations (of motion, say) in two reference systems, as in a smoothly rolling and a vehemently jerked car, does not at all mean sameness of phenomenal behaviour for the passengers of these two vehicles."[90]

If Silberstein is correct in what he says about the inability of the general principle of relativity "either to predict or exclude anything which has a phenomenal content"—and his statement to that effect does not stand alone—then it is a principle incapable of confirmation. For things which have a phenomenal content are coextensive with what may appear to human beings, and hence include all facts open to their observation. A principle which neither predicts nor excludes facts is one which cannot distinguish between facts and non-facts, and though such a principle may be a good guide to guessing, and have a place in science because of its power to suggest, it cannot be the expression of a law of nature.

As shedding further light on the doubts generated in the minds of physicists by Einstein's circuitous, dimensional method of "explaining" the universe, consider the

[90]Silberstein, L., *General Relativity and Gravitation*, pp. 22, 23, 24.

following passages from Bridgman's *The Logic of Modern Physics:*

"The fundamental postulate that the laws of nature are of invariant form in all coördinate systems is highly mathematical, and of an entirely man-made character. Of what concern of nature's is it how man may choose to describe her phenomena, and how can we expect the limitations of our descriptive process to limit the thing described? Furthermore, Einstein's method of connecting his mathematical formulation and nature by way of coincidences of 4-events (three space, one time coördinates) seems to be very far removed from reality, since it entirely leaves out the descriptive background in terms only of which the 4-event takes on physical significance. Nevertheless, three definite conclusions about the physical universe have been taken out of the hat by the conjuror Einstein (shift of the perihelion of Mercury, displacement of apparent position of stars at the edge of the sun's disk, and the shift toward the infra-red of spectrum lines from a source in a gravitational field), and the problem for us as physicists is to discover by what process these results were obtained" (pages 171, 172).

"I personally question whether the elements of Einstein's formulation, such as curvature of space-time, are closely enough connected with immediate physical experience ever to be accepted as an ultimate in a scheme of explanation, and I very much feel the need for a formulation in more intimate physical terms" (page 176).

"In view of all our present difficulties it would seem that we ought at least to try to start over again from the beginning and devise concepts for the treatment of all optical phenomena which come closer to physical reality. . . . I believe that it is a very serious question whether we shall not ultimately see such a change, and whether Einstein's whole formal structure is not a more or less temporary affair" (page 165).

In view of previous discussions, the significance of these passages will probably not escape the reader. The last one to be sure, refers to optical phenomena only, but the context, which is too long to quote, indicates that the doubts expressed extend to the whole field of relativity.

Now how are we to reconcile the judgment of these four authorities on relativity (Bridgman, Campbell, Painlevé and Silberstein) that the general theory of relativity cannot explain anything, with the judgments of authorities at least equally qualified (expressed in Section 22), that it does explain the gravitational and inertial behavior of bodies? Does it not reduce to the question of what is meant by an "explanation"? If by an explanation we are to understand *any* means of successfully inferring facts, then the equations of relativity provide explanations, since they are a means of successfully inferring certain facts; and explanations of this character we may call *x*-explanations. But if by an explanation we are to understand a means of successfully inferring facts which enables us to perceive a causal connection between the facts inferred and those from which they are inferred—which may be called a *y*-explanation—then the equations provide no explanations, since they propose no intelligible cause for the phenomena they infer. The alleged causes are expressed in phrases, such as "curvature of space-time" and "inertia-gravitation," which are mere synonyms for "something or other," and misleading ones, because, unlike this more honest synonym, they appear to convey information about the characteristics of the cause without really conveying any. They add nothing, except confusion, to the bare empirical fact that if the new definitions are substituted for the old ones, explanatory powers appear, leaving entirely unanswered the question, Why? What the

critics of Einstein's method of "explaining" quoted above, evidently perceive is that these new definitions and units, like all others, are man-made things, and hence nature, unless she is man-made also, cannot be determined by them. Yet they also perceive that Einstein has succeeded, somehow, in conjuring *x*-explanations "out of the hat" by simply juggling definitions and units, just as similar explanations of the *d*- and *l*-effects were conjured by similar methods in Chapter II. And they are mystified by what means he has done it. For new definitions and units possessing the powers of physical causes are a novelty unknown before the vogue of relativity. Certainly the old definitions and units had no such powers. The key to the mystery evidently is to be found in dimensional explanations, which are *x*-, but not *y*-explanations.

The radiation theory therefore confirms most relativists (and many facts) in predicting the power of the equations of relativity to explain and predict, but it also justifies* the reasoning of the dissenters mentioned in this section by revealing the peculiar dimensional character of the explanations and predictions which these equations provide. In short, the equations do not get their explaining and predicting power from any new "discoveries" about, that is, definitions of, "space" and "time," as is generally assumed. Definitions alone can only reveal truths which are true "by definition." They get this power from the fact that they happen to represent a dimensional disguise for a part of the physical mechanism whose operations control the changes, at least the material and radiational

*This does not mean that there are not other justifications. Apparently predictions from the general theory are obtained only by more or less arbitrary selections from various alternative solutions, on grounds of "simplicity," etc. The equations suggest predictions rather than require them. Hence doubt about what they predict and what they exclude.

changes, of the universe. Were the universe static, as the relativists assume, the power would depart from them, just as the power of the new definition of time (given on page 27) to explain and predict the *l*-effect would depart from it, were the earth a perfect rotationless sphere, as there assumed. Thus *not* allowing for the velocity of light in their definitions of length and time (see page 5), is only a back-handed way *of* allowing for the Doppler-displacements inseparable from the motion of material, and hence radiating, bodies. Failure in correcting for the former, therefore, means success in correcting for the latter; the consequence being that Einstein's *equations* fit the facts of relative motion, while his *assumptions* only serve to conceal why they do it.

CHAPTER VIII

SUGGESTIONS TOWARD THE EXTENSION OF THE RADIATION THEORY

EVIDENCE adduced in previous pages, and particularly in Chapter V, indicates that the theory of a cosmic mechanism of radiation is foreshadowed in the expressions of many distinguished physicists, from Maxwell and Tait to Thomson, Einstein and Millikan. Indeed, the whole trend of modern physics appears to be in the direction of such a theory, the wave mechanics ideas of DeBroglie, Schrödinger and others being particularly suggestive thereof. That this foreshadowing of a radiation theory, however, dates even further back, to predecessors certainly not less eminent, may be inferred from the following interesting passage from Poynting:

"In addition to his experimental discoveries, which place him first in the rank of physicists, Faraday has given us a hypothesis as to the nature of physical actions which is now universally held, the hypothesis which regards all actions as transmitted to the body acted on through the surrounding medium. Strictly speaking, Faraday only revived this hypothesis, for it is the most natural one, and it was, I believe, generally accepted before the time of Newton. When in common experience we produce action on other bodies by our own exertion we require some connecting matter to transmit our energy. It was at first felt as a difficulty in Newton's theory of universal gravitation that no mechanism was known to exist which could transmit the action from sun or planet to planet. It was forgotten that Newton's theory was merely a description

of the observed motion of the planets, showing how that motion varied with their relative positions; with the addition of a guess that similar actions would be found to take place in all matter varying similarly with relative position—a guess since verified by laboratory experiments. The simplicity with which the theory could be stated in terms only of the distance of the bodies apart, and without reference to any intervening mechanism, seems to have led to the supposition that none existed. Newton, however, was clearly of opinion that the action required a medium for its transmission, and Faraday claims him as supporting the view that in the case of gravitation towards the sun 'the power is always existing around the sun and through infinite space, whether secondary bodies be there to be acted upon by gravitation or not,' and this 'is, in philosophical respects, the same as that admitted by all in regard to light, heat, and radiant phenomena; and (in a sense even more general and extensive) is that now driven upon our attention in an especially forcible and instructive manner, by the phenomena of electricity and magnetism, because of their dependence on dual forms of power.' (*Exp. Res.*, vol. 3, p. 574.)"[1]

From this the following inferences seem justified: First, the idea that gravitation is not an action at a distance, but an influence transmitted by some definite mechanism through an "intermediary medium," as Einstein calls it, goes back at least to Newton. Second, the idea that this mechanism is dynamic, in the sense that a "power is always existing around the sun" and "is in philosophical respects the same as that admitted by all in regard to light, heat and radiant phenomena," goes back at least to Faraday. The radiation theory then is able to point to implications which give it a long and noteworthy lineage.

At the close of Chapter IV, however, it was pointed out

[1]Poynting, J. H., *Collected Scientific Papers*, pp. 576, 577.

that the radiation theory is necessarily provisional and over-simplified. It is the universal experience of science that as phenomena receive more and more critical examination, greater and greater complexities appear, and we cannot doubt that this will be found true of the phenomena unified by the radiation theory. In the stage of development reached in the foregoing exposition, that theory can be but a part of something more comprehensive and complex, a first approximation, much too over-simplified to represent the actual situation. That this expectation is justified is indicated by the facts of electricity and magnetism, facts to which little attention has been paid in previous pages. The correlation of these facts with those of gravitation, however, is unmistakable, and indicates that a somewhat similar mechanism, operating through a similar medium, is involved. For electric and magnetic influences not only move through space with the same velocity as light, but they are subject to the same inverse square law, and apparently to the same Doppler-like (relativity) effects. This is recognized by the relativists in their attempts, in some cases successful attempts, to extend their formulæ to include the phenomena of electricity and magnetism. In this connection it is also of interest to observe that chemical phenomena are coming to be recognized as electrical in nature, so that a unification of natural forces, moving with the velocity of light, appears to be a goal to which physical investigation is tending. This is in the nature of a verification of the radiation theory, requiring, as it does, an immanence of influences moving with the velocity of radiation from point to point in space.

The facts of electricity and magnetism, however, indicate that the mechanism is more complicated than might be inferred from those of gravitation and inertia alone.

It is evidently of a dual nature. Indeed, to realize this we need seek no further than the phenomena of static electricity, among which the distinction between positive and negative charges is so conspicuous a feature. That the phenomena of electric currents and magnetism arise from the movement of statically charged particles (protons and electrons) is a view generally accepted among physicists, and if this view is correct, the fundamental mechanism of electromagnetism must be traceable to characteristics of statically charged bodies and their reactions with the ether.

Now the law of attraction of dissimilar charges is the same as that of gravitation, except that the force per unit of mass is capable of becoming very much greater. Moreover, the evidence that the velocity of propagation of the attraction is the same as that of light is stronger than in the case of gravitation. The evidence of deviations from classical laws at high velocities is also clearer, as shown by experiments on the deflection of fast-moving electrons in electric and magnetic fields. Indeed, the resemblance between the phenomena of gravitation and those of statically charged bodies, whether of attraction or repulsion, is such that some intimate connection between their causes is irresistibly suggested. And this calls for an extension of the radiation theory into the realm of electromagnetism. Owing to lack of data the method of extension is obscure, but it is clear that static attraction and repulsion must be attributed to unbalanced radiation pressure of some kind, essentially similar to that which causes gravitation. That the attractions and repulsions of so-called static charges are really dynamic in nature is no new suggestion. Not only does Tait in the quotation on page 117 insist that this is the case, but Preston, among others, suggests the same thing. Thus he says:

"The work spent in producing the electrification of a conductor is spent on the ether and stored there, probably as energy of motion."[2]

The radiation theory simply renders this suggestion more specific; yet the gaps in our knowledge preclude any confident expression of just what the mechanism is. Provisional hypotheses nevertheless may be surmised, and we shall content ourselves with presenting one of several which might be proposed.

We may assume, for example, that *I*-radiation, instead of being of one kind, is of two. In short, that the modification of radiation which constitutes matter is a dual modification, one variety of which makes up protons, and emits what may be called *P*-radiation, the other making up electrons, which emit what may be called *E*-radiation. We may make the further assumption that *P*-radiation is strongly re-radiated by protons, but weakly by electrons, and that *E*-radiation is strongly re-radiated by electrons, but weakly by protons; a rather natural assumption in view of the known tendency of radiating bodies to selectively re-radiate the kind of radiation which they selectively emit. If we retain the assumption made in Chapter IV, that the radiation affords a push rather than a pull mechanism, it will follow from these additional assumptions, that protons will repel protons and attract electrons, whereas electrons will repel electrons and attract protons, as required by the facts of static electricity. Moreover, the attractions and repulsions will follow the inverse square law, will move with the speed of light, and will be subject to Doppler-displacements, as the facts also seem to require. Such an extension of the radiation theory,

[2]Preston, Thomas, *The Theory of Light,* 2d edition, p. 537.

therefore, would account for at least the primary phenomena of static electricity. *G*-radiation and the consequent attraction of gravitation is apparently most plausibly interpreted either as longitudinal radiation, or as a residual inefficiency effect of rather feeble character, incident on the transformation of ethereal radiation into *E*- and *P*-radiation.

It is to be noted that this view of the nature of static attractions and repulsions does not require that, in the familiar phenomena of neutralization, any actual annihilation of forces shall occur. There is no mutual destruction of forces, which may be made to appear again by separation of the charges. The apparent destruction is simply a compensation effect, analogous to the many other such effects to be found among radiation phenomena. The *E*- and *P*-radiation persists after neutralization as vigorously as before, but the combined effect of the juxtaposed emitting units is such as to cause a compensation, so far as producing attractions and repulsions is concerned. The exact distribution of the charges in juxtaposition is, to be sure, unknown, but it is evidently a distribution associated with some position of stable equilibrium. A certain degree of confirmation of this view of the nature of neutralization is afforded by the fact, first noted by Faraday, that no electric field exists within a closed conducting vessel caused by electric charges without it. In this case the neutralization within the vessel is clearly caused by a compensation effect, due to the distribution of the external charges under the influence of their mutual reactions to reach equilibrium, and is attained without juxtaposition of positive and negative charges and without neutralization except within the vessel. This shows there is no actual destruction. The fact is that if the dynamic concept of

force maintained by Tait, and required by the radiation theory, is accepted, neutralization must be a phenomenon of compensation and not annihilation of forces.

Whether ethereal radiation itself is of a dual character, corresponding to that emitted by matter, is perhaps problematical, but apparently it is. At any rate, if it is not, we must assume the gradual transmutation of *E*- and *P*-radiation into a common form of ethereal radiation in the course of its passage through space.

It is rather natural to surmise that the difference between *E*- and *P*-radiation may be the difference between the right- and left-handed (clock-wise and counter-clock-wise) polarization of ethereal radiation; and if we assume this polarization to be circular, its whole energy would be energy of motion, and hence anything in the nature of merely "potential" energy, even in the ethereal medium, would be eliminated. This would constitute a very satisfactory picture of the conditions obtaining in space, but we must recognize its speculative character, since nothing corresponding to the selective repulsion of polarized radiation has been experimentally encountered. Such failure, however, may be because it has never been looked for. Indeed, the realms of radiation pressure and momentum are almost completely unexplored by experiment and this, among other reasons, explains why the consequences of the radiation theory remain so much in doubt. Experimentation in these realms is, nevertheless, entirely feasible, and the promise it affords of throwing light on many obscure yet fundamental processes of nature should stimulate physicists to undertake it.

When we extend our surmises beyond the simpler phenomena of electricity represented by the reactions of static charges, and seek an explanation of the attractions and

repulsions of direct electric currents for one another, a difficult situation is encountered. At least, no plausible explanation of these phenomena occur to me. The attractions and repulsions are evidently due to the movement of the charges which constitutes the current, but this movement is apparently too slow to afford any explanation based on the hypothesis of Doppler-displacements. I have not indeed attempted to examine this matter very closely in the light of various modifications of the radiation theory, but such modifications as I have examined appear unpromising. Perhaps it is best at this point to meet the questions raised by the problems of galvanic electricity with an admission of the inability of the radiation theory, in its present stage of development, to explain them. However, as no alternative theory can do any better, we may be reconciled to this weakness and trust that the future may remove it.

The explanation by the radiation theory of at least some of the phenomena of alternating currents would appear easier than of direct, because they involve acceleration of the electrons. Apparently the pulses generated are of the same general nature as those of light. The fact that in currents generated by a make-and-break mechanism, the break pulses are of greater intensity than the make, is in harmony with this view, the retardation of the electrons on cessation of the current being a more rapid change of motion than their acceleration on its inception. The correspondence of this mode of generation of pulses with the assumed mode of origin of light described in Chapter V, Section 13, is obvious.

The problems of magnetism are probably not separate from those of galvanic electricity, since it seems fairly plain, and is generally accepted, that magnetism is caused

by electric currents, magnets and solenoids having identical reactions to electric and magnetic forces. Magnetism, therefore, seems to offer no additional difficulty to the radiation theory, since an explanation of galvanism on the lines of that theory would presumably involve an explanation of magnetism also.

While there is little to say in this realm of physics in support of the radiation theory, one set of phenomena of electromagnetism is very suggestive of ordinary mechanical effects, presumably amenable to explanation by the radiation theory. Magnetism is apparently due to rapidly revolving electric charges, and there is good evidence that such charges possess inertia. Now it is a well-known fact that a conductor conveying a current in a magnetic field moves, not in the direction of the lines of magnetic force, but at right angles to them, and a magnetic pole reacts to the current in a reciprocal manner, moving neither toward nor away from it, but at right angles. Furthermore, the direction of motion will in both cases be reversed if the direction of the current or the sign of the magnetic pole is reversed. The resemblance of these peculiar reactions to those of the mechanical reactions of gyroscopes is very suggestive. For it is a fact experimentally demonstrable that when a transverse force is impressed upon the axis of a rotating gyroscope, tending to change its orientation, the axis moves, not in the direction of the impressed force, but at right angles thereto, and in a direction which will be reversed if the direction of rotation of the gyroscope be reversed, or the direction of the impressed force. If the impressed force is due to unbalanced radiation pressure, then the axis will move in a direction at right angles to the component thereof which tends to transverse deflection, the peculiar reaction of the gyroscope thus

being due to an inertial reaction combined with one due to unbalanced radiation pressure. And as inertial reactions are traceable to reactions with the radiant ether, we are led to surmise that the analogous electromagnetic behavior of magnets, solenoids and electric currents may be due to a corresponding combination. This, of course, is only a surmise, and mathematical treatment is called for before its plausibility can be estimated. But it is at least suggestive that accepted theories of magnetism assume reacting units which, on account of the inertia of their revolving electrons, would act like gyroscopes. Furthermore, there is some evidence that the electron itself is a revolving and hence a gyroscopic structure. And if the electron, why not the proton also? The radiation theory, therefore, holds out some promise of eventually reducing the electromagnetic and mechanical behavior of bodies to a common basis, and thus reducing all change of motion to uncompensated and hence unsymmetrical interchange of radiant energy.

It may at first sight be considered a weakness of the radiation theory, when extended to electrical phenomena, that it appears to reverse Maxwell's theory of light and other forms of radiation. Maxwell attributed radiation to electric and magnetic forces, whereas the radiation theory attributes those forces to radiation. This reversal, however, is not so serious a criticism as it may appear, since Maxwell does not suggest the nature of the "forces" whereby he explains radiation, although he gives them names. He, therefore, does not, as the radiation theory does, reduce them to anything with which human beings are familiar. Moreover, it can be shown that the pressure of radiation, and hence its capacity to produce the effects on matter which the radiation theory attributes to it, can be inferred entirely independent of Maxwell's theory, and

hence independent of his rather mysterious "forces"—which cannot, in any event, be proved to be *non*-radiation. Thus Poynting says:

"Though this pressure [of radiation] was first deduced as a consequence of the Electromagnetic Theory, Bartoli showed, independently, that a pressure must exist without any theory as to the nature of light beyond a supposition which may perhaps be put in the form that a surface can move through the ether, doing work on the radiation alone and not on the ether in which the radiation exists. Professor Larmor has given a proof of this pressure and has shown that it has the value assigned to it by Maxwell, viz., that it is numerically equal to the energy-density in the incident wave, whatever may be the nature of the waves, so long as their energy-density for given amplitude is inversely as the square of the wave-length."[3]

The reversal of Maxwell's theory of radiation does not, as a matter of fact, contradict it, since there is nothing in that theory which *denies* that electric and magnetic forces have their origin in radiation. Moreover, as the passage above quoted indicates, the view of the ether required by the radiation theory is in entire harmony with the conclusions of Bartoli, since ethereal radiation *is* the ether, and there is no reason to infer that a body moving uniformly through it is called upon to do any work upon it. If, on the other hand, some form of non-radiation pervades space, there is no positive evidence that work upon it can be done by matter.

The foregoing brief suggestions relative to the extension of the radiation theory into the domain of electromagnetism must suffice for our present purpose. They show that the form of radiation theory expounded in earlier chapters is only the beginning of something. Nor

[3]Poynting, J. H., *Collected Scientific Papers*, p. 317.

is it, strictly speaking, a real beginning. It is rather an explicit and somewhat more specific statement of the implications of a radiant ether to be found scattered through the literature of physics. The beginning, therefore, dates back at least as far as Faraday. But it can claim to be a significant extension of the ideas of earlier physicists, and a useful fragment perhaps of the ideas of those to come. Present knowledge certainly leaves many gaps in it, and development thereof no doubt will reveal a number of erroneous assumptions in the formulation herein suggested. The theory in its present stage is a rather blind groping for the truth, but the evidence now available apparently reveals no path that is plainly marked. If the groping is in the right general direction we may perhaps be satisfied. The radiation theory, however, though incomplete is a unifying one, and in this respect, at least, fulfils the aspirations both of science and philosophy. Cosmic forces are obviously of impressive complexity, but as knowledge advances indications appear that amid this complexity an identity is gradually revealing itself. The phenomena of physical nature converge and assume common characteristics—those of radiation—which seem nowhere absent from space. Thus if the chain of evidence presented in previous pages, and particularly the crucial link therein supplied by the relativity theory, is not deceptive in strength, we may remain confident that the explanations of nature's laws are physical, not metaphysical, and that science is in process of revealing to men a progressively more unified, more inspiring, and more comprehensible universe.

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